Members are asked to contribute discussions of papers in this issue of the Journal for publication in the next issue.

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ISSUED QUARTERLY.

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OF THE

New England Water Works Association.

1925—1926.

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THE ASSOCIATION was organized in Boston, Mass., on June 21, 1882, with the object of providing its members with means of social intercourse and for the exchange of knowledge pertaining to the construction and management of water works. From an original membership of only TWENTY-SEVEN, its growth has prospered until now it includes the names of 800 men. Its membership is divided into six classes, viz:

A Member shall be an officer or employee of a public or private water works, an engineer, chemist or other person qualified to aid or interested in the advancement of knowledge relative to water works.

An Honorary Member shall be a person of acknowledged eminence in some branch of water supply or of engineering.

A Life Member shall be a member whose service to the Association entitles him to special recognition by the Association.

A Junior shall be not less than eighteen years nor more than twenty-five years of age, a student or connected with water supply work.

An Associate shall be either a person, firm or corporation engaged in manufacturing or furnishing materials or supplies for the construction or maintenance of water works.

A Corporate Member shall be either a Water Board, Commission, Company or Municipal Corporation.

The initiation fees and annual dues are as follows:

	Initiation Fees		*Annual Dues*
Members	$ 3.00	Members	$ 6.00
Juniors	1.00	Juniors	3.00
Associates	10.00	Associates	20.00
Corporate Members	10.00	Corporate Members	10.00

This Association has six regular meetings each year, all of which, except the annual convention in September, are held at Boston.

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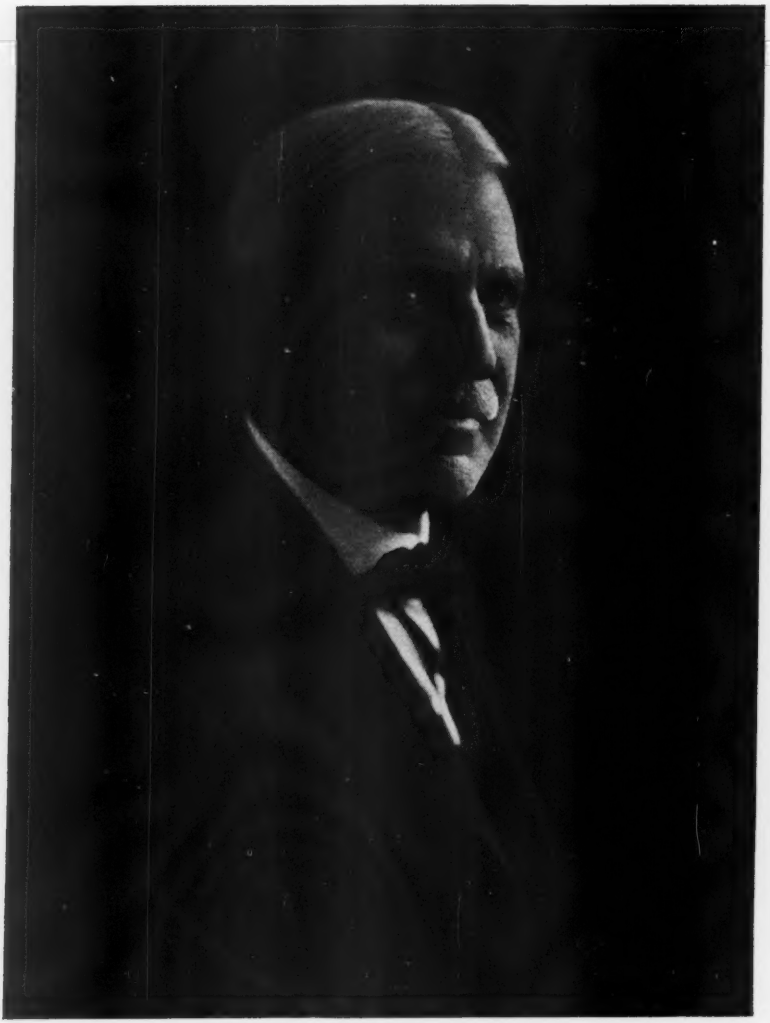


THEODORE L. BRISTOL,
President of the New England Water Works Association.
1925–1926.

New England Water Works Association

ORGANIZED 1882.

Vol. XL. March, 1926. No. I.

This Association, as a body, is not responsible for the statements or opinions of any of its members.

THE IMPROVEMENT OF THE WATER SUPPLY OF KEENE, N. H.

BY ROBERT SPURR WESTON AND G. A. SAMPSON.*

[*Read January 12, 1926*]

Without any change in source, the fire hydrant service of the water supply of Keene, N. H., has been improved in pressure and increased in volume at the center of the city from 1 500 to 4 000 gal. per min. at 60 lbs. pressure (the latter volume equivalent to 2 900 gal. per min. at 75 lbs. pressure) and at the same time the quality of water has been materially improved. The description of the work involved is as follows:

The city of Keene, the prosperous seat of Cheshire County, New Hampshire, and one of the most beautiful cities of New England, has been supplied with water for many years, originally from Goose Pond, also called Sylvan Lake, and more recently from a series of reservoirs on Roaring Brook. The city is quite compactly built about a central square where the main buildings are located, and along the streets which radiate from it. Most of the built section of the city is on the plain of the Ashuelot River, at elevations of from 475 ft. to 525 ft. above sea level. To the east rises Beech Hill with elevations of about one thousand feet within only a mile and a quarter of Central Square. This topography is excellent from a water-supply standpoint. (See Fig. 1.)

Population. During the past twenty years Keene has grown steadily, and this growth may be expected to continue. The existing and estimated populations are as follows:

Year	Population	
1880	6 784	
1890	7 446	
1900	9 163	
1910	10 068	
1920	11 210	
1930	12 300	Estimated.
1940	13 400	,,
1950	15 000	,,

* Consulting Engineers, 14 Beacon Street, Boston, Mass

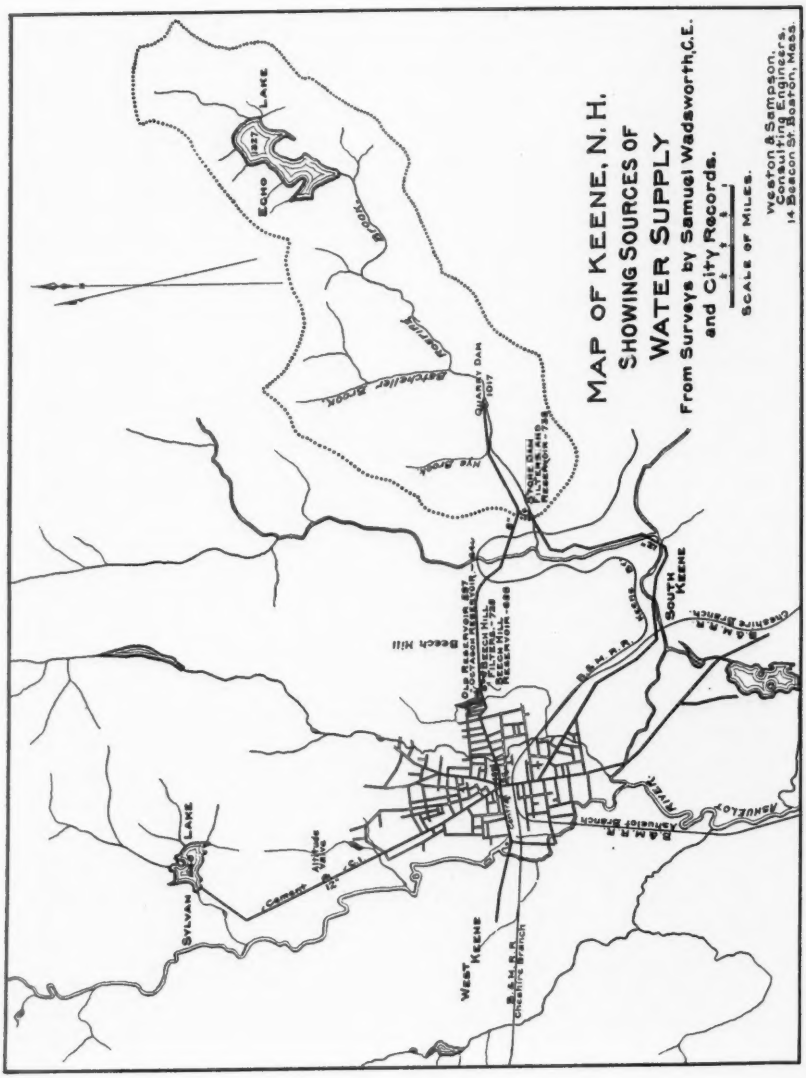

MAP OF KEENE, N. H.
SHOWING SOURCES OF
WATER SUPPLY
From Surveys by Samuel Wadsworth, C.E.
and City Records.
SCALE OF MILES.
Weston & Sampson,
Consulting Engineers,
14 Beacon St. Boston, Mass.
ECHO LAKE
Elevation 1227
Beaver Brook
Roaring Brook
Butterfield Brook
Nye Brook
Granby Dam
1017
Pisgah Brook Reservoir
Old Reservoir
Joseph Hill Filter Reservoir
Beech Hill
B. & M. R.R.
Cheshire Branch
Ashuelot Branch
SOUTH KEENE
WEST KEENE
SYLVAN LAKE
Camera Station
Ashuelot River

Fig. 1.

Consumption. The present average consumption is 1 800 000 gal. daily, or over 150 gal. per capita. This is high and probably includes considerable waste which may be found and eliminated.

Present Works. Sylvan Lake was the original source. This reservoir was formed by impounding the waters of a small brook by means of an earth dam, located 2.7 miles from Central Square in a northerly direction. It stores about 170 mil. gals. from a catchment area of a little over 2.0 sq. miles. A main leads from Sylvan Lake to Central Square. This consists of 12-in. pipe with the exception of short lengths of 14-in. and 16-in. pipes near the lake. Of this total length of about 16 000 feet, some 7 000 feet is cement-lined pipe, this portion being toward the lake.

The elevations of the other sources of supply are such that formerly water wasted over the spillway of Sylvan Lake daily. This loss was prevented by placing a 12-in. Golden-Anderson controlling altitude valve in the main. This valve is so set that the pressures in the city must fall below 65 lbs. per sq. in. before this source is drawn upon.

The principal supply is taken from Roaring Brook (see Fig. 1), a stream which enters the North Branch of the Ashuelot River about one mile north of South Keene, and drains the highlands to the east of the city, in the towns of Roxbury and Nelson. There are three dams on the brook known as Echo Lake Dam, Quarry Dam and Stone Dam, respectively.

Echo Lake (Elev. 1327) was formed by raising by 10 ft. a natural lake at the upper end of the brook. The contributory catchment area is 1.9 sq. miles and the storage of water in 150 acres, averaging about nine feet in depth is some 440 mil. gal. This lake furnishes stored water, which is let down the brook as required below.

Two and one-half miles below Echo Lake and just below Batchelder Brook is the Quarry Dam, from which an 8-in. pipe leads to the old Octagon Reservoir, 15 300 ft. away, and there connects with the existing distribution system. This pipe was laid in about 1886. The Quarry Dam provides little storage, being designed as a high-level intake. The catchment area above this dam is 4.9 sq. miles.

The Stone Dam 0.60 mile below the Quarry Dam, originally impounded about two mil. gal., which has been reduced to 1.5 mil. gal. by the construction of filters within it. The catchment area above the dam is 6.0 sq. miles. Water is brought from the Stone Dam to the junction of Marlboro Street and Eastern Avenue through 15 000 ft. of 12-in. pipe, laid in about 1902, and paralleled for some 2 800 ft. above the junction point with an auxiliary line of 8-in. pipe. In 1924, the 5 000 ft. of 6-in. pipe which formerly conveyed water from Eastern Avenue to Main St., was replaced with 14-in. pipe. The distance from the Stone Dam to Central Square on Marlboro and Main streets is about 21 600 ft.

Storage for fire hydrant service was originally provided for Sylvan Lake water in the Beech Hill impounding reservoir (Elev. 597), built in

1872. It stores 13 mil. gal. and is useless for maintaining pressures of over 50 lbs. in Central Square. However, it constitutes a fire reserve for conflagrations.

The Octagon Reservoir, finished in 1886 (Elev. 640), with flow line 43 ft. higher than that of the old Beech Hill reservoir and designed to store one mil. gal. of water, and to maintain fire hydrant pressures of from 55 to 60 lbs. at Central Square, is also located on Beech Hill, but owing to excessive leakage has never been of practical use.

Elevations. The important elevations of the works which existed in 1924 are as follows:

Place	Elevation feet
Sylvan Lake, flow line	640
Old Beech Hill Res., flow line	597
Echo Lake Dam	1 327
Quarry Dam	1 017
Summit of pipe on Beech Hill	866
Stone Dam	738
Octagon Reservoir, flow line	640
Keene, Central Square	489
West Keene	505
South Keene	560

Fire Hydrant Service. On August 5, 1922, Professor H. K. Barrows of Boston made a report on methods of obtaining adequate fire hydrant pressure and supply. He found, from hydraulic tests, that when the pressure in Central Square was 60 lbs. per sq. in. the discharge available for fire streams would be 1 500 gal. per minute, or, in his opinion, less than one half of that necessary. His tests showed that the 12-in line from the Stone Dam had a carrying capacity of only a little over two-thirds of what it would be with pipe fairly new and in good condition, and the 8-in. pipe from the Quarry Dam a capacity of about one-half that of new pipe.

Professor Barrows recommended that 3 400 gal. of water per minute at a pressure of 60 lbs. per sq. in. at Central Square, be provided, and to do this, he recommended that the Octagon Reservoir be repaired, the distribution system be enlarged, and a new main be laid to the Stone Dam. He also recommended the cleaning of the mains, a valve to prevent waste through Sylvan Reservoir, and a general improvement of the distribution system.

While the use of the Octagon Reservoir seemed unwise to the city officials both because of its structural condition and also its inability to furnish fire hydrant water under pressures of 75 or 80 lbs. per sq. in., as demanded by modern conditions, Professor Barrows' other recommendations were accepted. The 8-in. line from the Quarry Dam was cleaned, increasing its capacity from 538 500 gal. to 914 400 gal. daily; even larger pipe was used for replacements in the distribution system than recommended; the controlling altitude valve, already mentioned, was placed in

the line to Sylvan Lake; and a new reservoir storing 1.5 mil. gal., with flow line at Elev. 698 ft., was built on Beech Hill.

Professor Barrows stated that there was an ample supply of water, and assumed that because it ran from a so-called unpolluted catchment area, it was of excellent quality. But subsequent to his report an event occurred which nullified this assumption.

The Epidemic of Gastro-enteritis. On or about October 16, 1923, many of the inhabitants of Keene and many of its visitors suffered from acute attacks of gastro-enteritis. While these attacks were usually of short duration, they were severe, and the State Board of Health was notified. Mr. Charles D. Howard, the Board's Chief of Division of Chemistry and Sanitation. found Bact. coli in samples of water collected from the Roaring Brook supply, and recommended that the water be chlorinated. The U. S. Public Health Service promptly condemned the water for Interstate Commerce, and posted a notice over the tap at the railway station, condemning the water for drinking. The ignominy of this notice was too disturbing to be ignored by the people of Keene, and they became aroused.

They soon segregated into two main groups. One of these argued that the pollution of the Roaring Brook source was unbelievable. Only four people inhabit the 6.0 sq. miles of catchment area, and the others who go on it are water-works' employees, infrequent fishermen, wood-cutters and trampers. Furthermore, the city owns nearly all of the land below the Quarry Dam and much of that above, even though the brook for nearly two miles above the dam be privately owned. Echo Lake, the main reservoir, is surrounded by city property on which there is thick second-growth; the roads about it are closed; and the inspection is good; all of which constituted good evidence of an "unpolluted" source.

The other group contended that even if the water were bad — and admittedly bad at certain times only — chlorination was an objectionable and unreliable remedy for a condition like that which had occurred.

Because of this lack of agreement, the matter was referred to the late Professor George C. Whipple, of Harvard University, and the writers, for report. After a careful study of the sources of supply, the reports and analyses of the State Department of Health, and the records of the Water Department, the following conditions were established:

It was not evident that the water of Sylvan Lake, derived from uninhabited woodland, and because of its low elevation seldom reaching the city, was in any way responsible for the gastro-enteric disturbances. On the other hand, it was judged to be hazardous to take the water of Roaring Brook, practically without storage, and draining a catchment area subject to accidental contamination from men and animals. Owing to the steep slopes of brook and catchment area, contamination is especially likely to occur at times of heavy rain, but even slight showers might be sufficient to carry polluting material into the brook and through the pipes to the city.

There was a considerable accumulation of leaves, twigs and silt in the mains. These conditions led to the following conclusions:

The epidemic of gastro-enteritis of October 16, was in all probability due to an infection of the water supply, but just how it occurred could not be judged from the evidence at hand. It may have been due to fecal matter wasted into the brook by the fall of 0.12 in. of rain on the 15th. It may have been due to the autumnal "overturn" of the water of Echo Lake which brought into action bacteria accumulated during the summer. It may have had some connection also with the fact that for several days prior to and during the epidemic, the deposits in the city mains were disturbed by drawing water to flush the sewers. Regardless of the epidemic, the supply was judged to be in danger of contamination at all times and in need of immediate remedy.

Careful study of the records of the State Department of Health showed that in previous years intestinal bacteria (Bact. coli) were found on various occasions, especially during the summer and autumn, but they also show that the frequency of occurrence of these organisms was greatest during the month of the epidemic. Therefore, it was an unusual concentration rather than an unusual presence which was responsible.

The color of Roaring Brook waters varies from 10 to 60 p.p.m. dependent upon the season of the year and the relative proportions of ground and surface water in the discharge of the stream. The average color is about thirty which is higher than modern standards permit.

Careful inquiry revealed that in the municipalities of Northern New England, supplied with natural water from upland sources, gastro-enteric disturbances are of frequent occurrence during the fall of the year. These disturbances affect students and commercial travellers most frequently, and it is probable that they are also due to gas-forming organisms of the Bact. coli group, but not necessarily those of human origin; B. Welchii (aerogenes), known to exist in soil, may be a contributing cause also. Mr. Howard believes that most of the Bact. coli which he finds in New Hampshire upland waters are of animal origin.

Remedies. Of the usual remedies, long storage was impracticable because of the lack of a suitable reservoir site. Chlorine was also impracticable, partly because it would neither reduce the rather high color of the water, nor remove the miscellaneous dirt which now enters the mains from the open brook, and partly because water containing so large and so variable amounts of organic matter might be chlorinated improperly and at those times taste of chlorine or be under-treated. The local difficulties connected with the maintenance of two chlorine applicators, one of which would have to be controlled manually, indicated against their use. Furthermore, health was not the only factor taken into account. It was recognized that the consumers justly demand an attractive and palatable drinking water.

Filtration was recommended as the simplest and most effective, although admittedly the most expensive, method of improving the character of Roaring Brook water, and the difficulties of attendance during bad weather which helped to decide against chlorination also led to the recommendation of slow filters rather than rapid filters using chemicals for treatment.

It was decided to build the filters at two separate locations, Beech Hill and Stone Dam.

Relation to Fire Hydrant Service. Because of the necessity for storing filtered water, both to equalize the flow through the filters and also to provide for fire hydrant service, a storage reservoir on Beech Hill to hold 1.5 mil. gal. was recommended, also additional lines of pipe from this point to beyond the Octagon Reservoir and from there to the center of distribution, the latter as recommended by Professor Barrows. It was also recommended that certain mains be cleaned and minor improvements be made.

Construction. The filters and reservoir were authorized by vote of Councils on July 25, 1924. Plans and specifications were ready on September 5, and on September 16 the contract was awarded to the S. C. Sperry Co., Inc., of Cambridge.

The contractor began work on September 25, 1924, and continued until December 16, when weather conditions made it advisable to suspend operations until the following spring. The excavation for the Beech Hill filter was finished and the concrete floors, walls, columns and roofs of the filter completed. Excavation for the Beech Hill reservoir was nearly completed.

Work was resumed on April 16, 1925, with special emphasis placed upon the completion of the reservoir to give the city this additional fire protection. This was accomplished on August 4, and the reservoir was gradually filled and tested with unfiltered water from the Beech Hill main. On September 3, filtered water from Beech Hill filter No. 1 was delivered to the reservoir and on October 2, both of the Beech Hill filter units were in operation furnishing filtered water to the city from the Quarry Dam source.

Excavation for the Stone Dam filter was begun on July 6 and the concrete work was finished on October 2. The two Stone Dam filter units were completed and filtered water supplied to the city from the Stone Dam source on December 9.

Beech Hill Reservoir.

The Beech Hill reservoir is of reinforced concrete, 112 ft. inside diameter by 20 ft. depth of water and has a capacity of 1.5 mil. gal. or sufficient to furnish 10 fire streams for 10 hours. The reservoir is surrounded with an earthen embankment and the roof is covered with 18 in. of earth to prevent freezing. Its flow line is at Elev. 698, thus giving a pressure of about 90 lbs. at Central Square. The reservoir is provided with a 16-in.

connection to the distribution system, a drain emptying into a nearby watercourse and an overflow discharging into the drain. The reservoir will be filled by the occasional excess of the Stone Dam filter over the consumption of the city and constantly by the Beech Hill filter, the total capacity of which discharges into the reservoir. An automatic float valve located in the effluent main of the Beech Hill filter will shut off this filter when the reservoir is filled and the excess of the unfiltered water entering the filter will overflow into a drain leading to the reservoir drain. The details of the reservoir are shown in Plate I and Fig. 2.

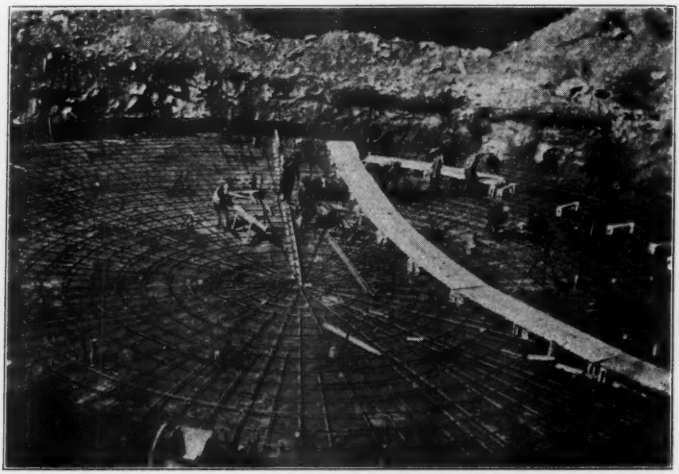


FIG. 2. — BEECH HILL RESERVOIR — REINFORCING STEEL FOR FLOOR SLAB.

BEECH HILL FILTER.

The Beech Hill filter is of the slow sand type and consists of two units, each 56 ft. 10 in. by 57 ft. 0 in. in area with a normal capacity of 375 000 gal. per day each, or a total capacity of 750 000 gal. per day and was constructed for the purpose of filtering the supply from the Quarry Dam previous to its delivery to the city.

The filtering materials consist of 12 in. of screened and washed local sand and 24 in. of medium size uniform sand dredged from the ocean near Ipswich, Mass.

The sand in the upper layer has an average effective size of 0.33 mm. and a uniformity coefficient of 1.55.

The construction is of reinforced concrete with an inverted groined arch floor in which the filtered water collecting channels are formed and a flat slab roof supported on circular columns and the filter walls. The filter is surrounded by an earthen embankment and the roof is covered by 18 in. of earth to prevent freezing. Four 36-in. manholes afford access to each unit for convenience in operation.

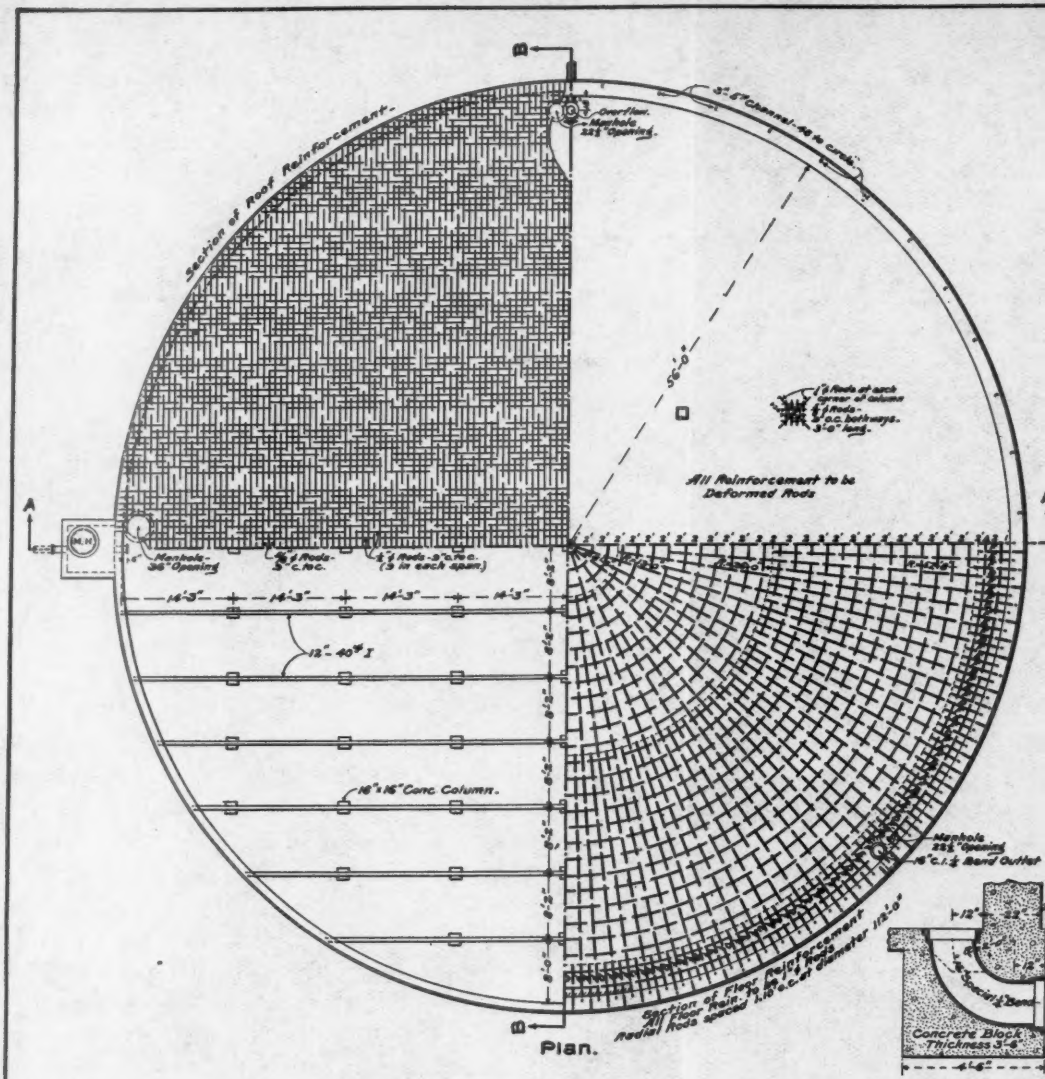
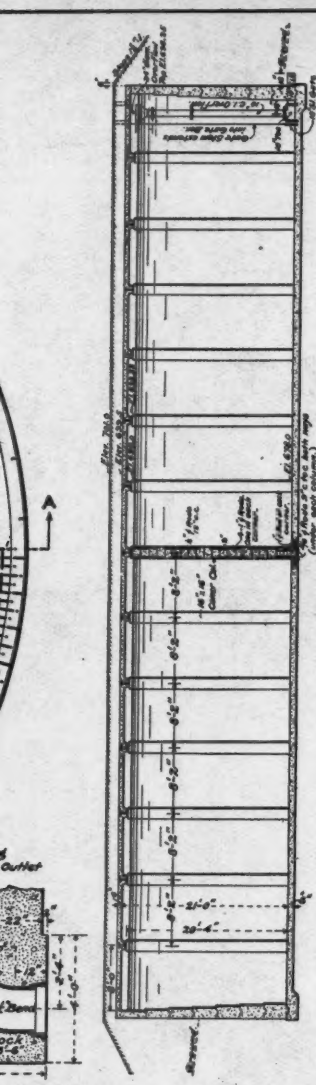
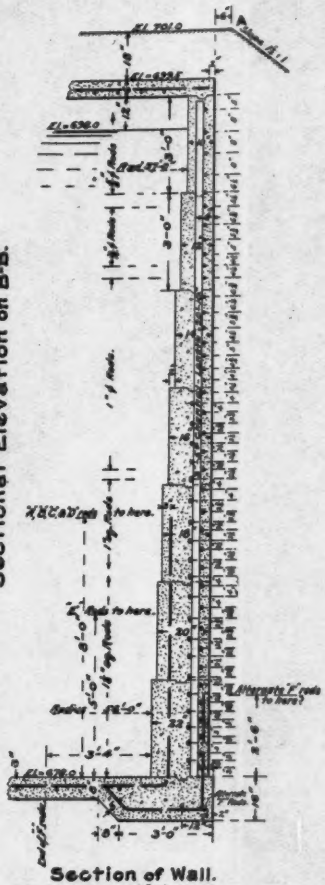

Section of Roof Reinforcement
3"x 5" Channel - 36 to Circle
Overflow
Manhole
22½" Opening
All Reinforcement to be Deformed Rods
Manhole
36" Opening
12"-40# I
18"x 18" Conc. Column.
Manhole
22½" Opening
16" C.I. ½ Bend Outlet
Section of Floor Reinforcement
All Floor Reinforcement to be ½" Rods
Radial Rods spaced 1'-10" c.c. at Diameter 112'-0"
Plan.
Detail of 16" C.I. Out
Scale 1"=1'.
Elev. 701.0
Elev. 699.0
Flow Line El. 698.0
Diameter 114'-0"
Iron Ladder
Elev. 679.0
Diameter 112'-0"
Sectional Elevation on A-A.
Scale 8"=1'.

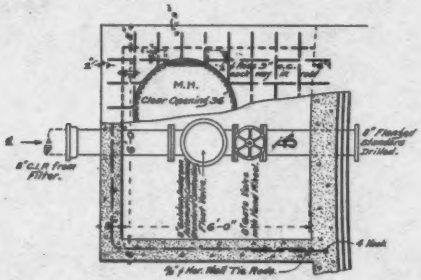
PLATE I.
N. E. W. W. ASSOCIATION.
VOL. XL.
WESTON AND SAMPSON
ON
KEENE WATER SUPPLY.



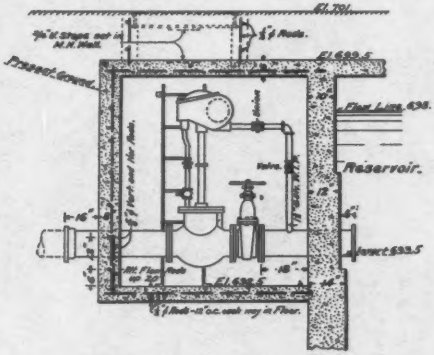
Sectional Elevation on B-B.



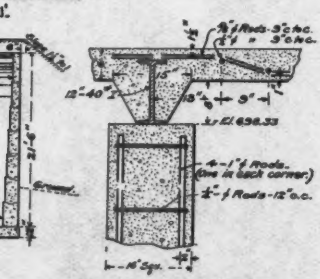
Section of Wall.
Scale ½"=1'



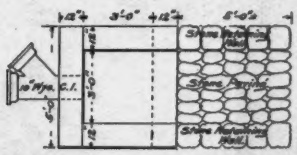
Plan



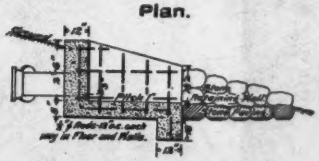
Sectional Elevation
REGULATOR WELL.
Scale ½"=1'



Scale 1"=1'.



Plan.

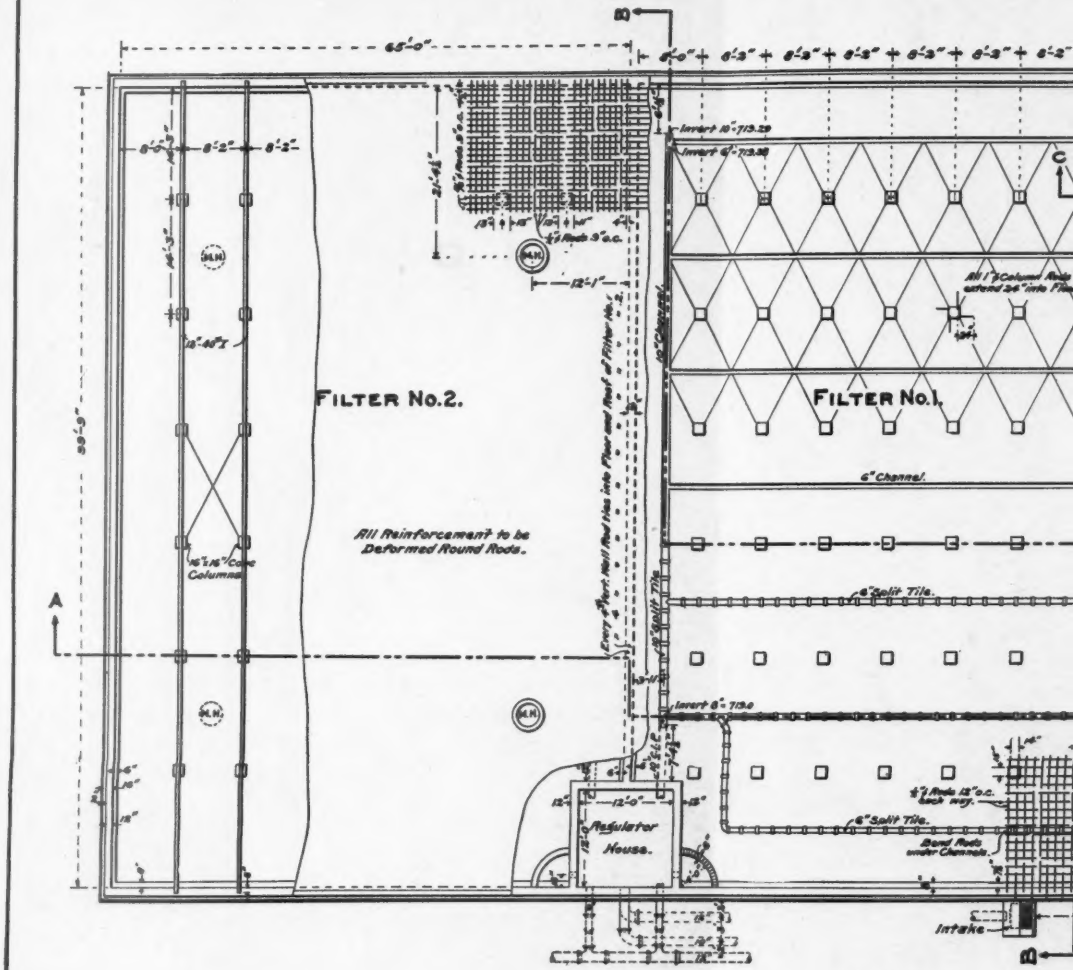


Sectional Elevation
DRAIN OUTLET.
Scale ¾"=1'

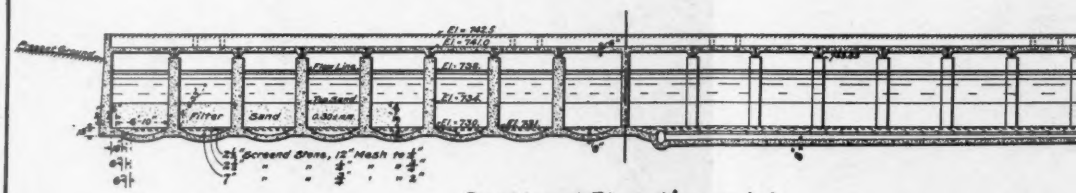
KEENE WATER WORKS
KEENE N.H.
CONCRETE RESERVOIR
Capacity 1,500,000 Gallons.
Scales as Noted.

August 1924.

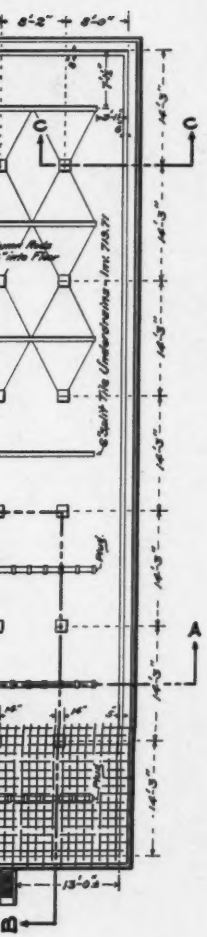
WESTON & SAMPSON,
Consulting Engineers.
14 Beacon St. Boston, Mass.

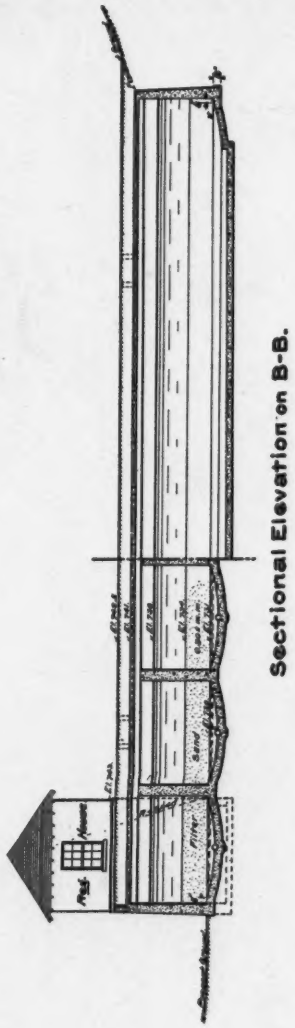


Plan.
Scale $\frac{1}{8}$"=1'.

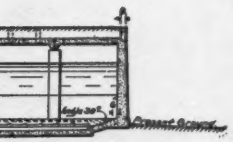


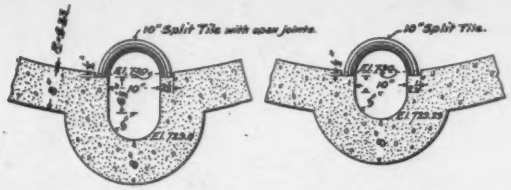
Sectional Elevation on A-A.





Sectional Elevation on B-B.

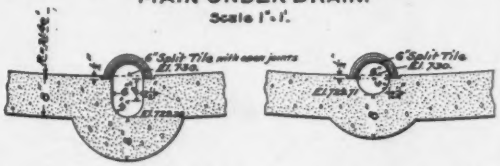




Section at Lower End. Section at Upper End.

MAIN UNDER DRAIN.

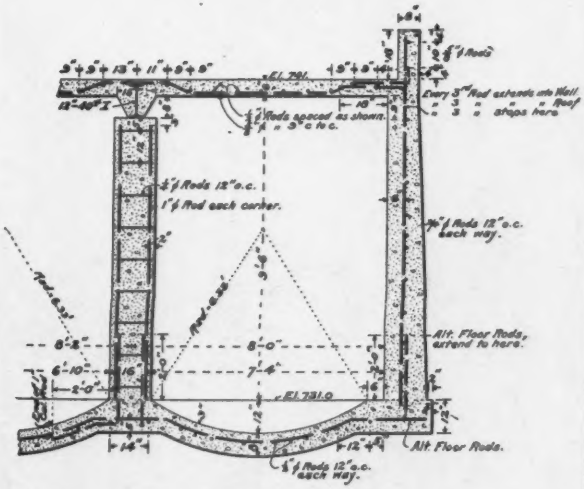
Scale 1"=1'.



Section at Lower End. Section at Upper End.

LATERAL UNDER DRAIN.

Scale 1"=1'.



Section on C-C.

Scale 1/2"=1'.

KEENE WATER WORKS

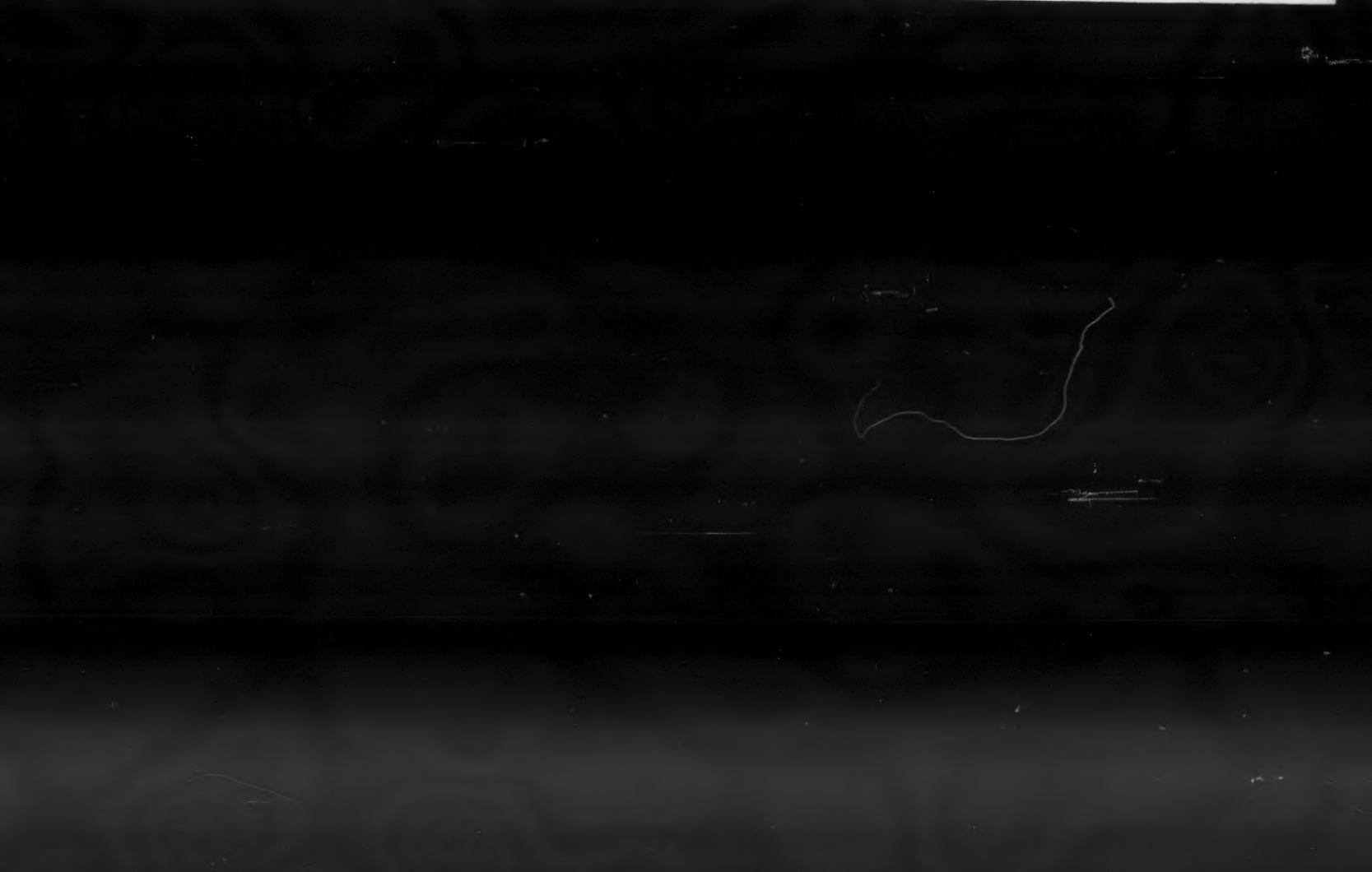
KEENE N.H.

STONE DAM FILTER

Scales as Noted.

AUGUST 1924.

WESTON & SAMPSON,
Consulting Engineers,
14 Beacon St. Boston, Mass.



A concrete regulator house with slate roof adjoins the filter and contains the Simplex rate controllers, loss of head gages, rate of flow gages equipped with weekly charts, gate valves and other control equipment.

The filter feeds directly into the Beech Hill reservoir and is provided with a drain and overflow discharging into a natural watercourse just south of the reservoir. In an emergency the Quarry Dam source may be turned into the city without passing through the filter.

Stone Dam Filter.

The Stone Dam filter is also of the slow sand type and consists of two units each 65 ft. 0 in. by 99 ft. 9 in. in area with a normal capacity of 1.5 mil. gal. per day. This filter purifies the supply from the Stone Dam reservoir previous to its delivery to the city.

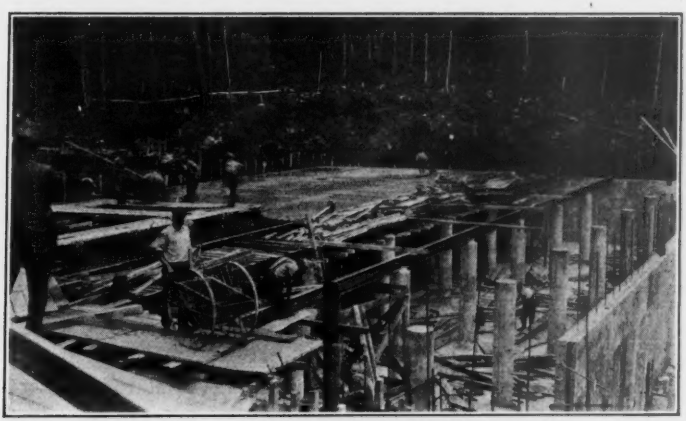


Fig. 3. — Stone Dam Filter During Construction.

The character and depth of the filtering materials are quite similar to those at the Beech Hill filter, although the depth of Ipswich sand is increased to 29 in. The type of construction and the devices for regulation are also like those at Beech Hill. The details are shown in Plate II and Figs. 3 and 4.

The sand in the upper layer has an average effective size of 0.35 mm. and a uniformity coefficient of 1.50.

An unique feature of this filter is its location. A careful study of the available sites below the reservoir showed the ground to be so irregular and difficult of adaptation that it was decided to build the filter in the reservoir. It was therefore necessary to drain the reservoir during construction and to supply the city by means of a temporary 12-in. main, extending to a diversion dam on the brook above.

The filter discharges directly into the 12-in. Stone Dam supply main

and is provided with a drain and overflow connected with the reservoir drain. There is an emergency connection for supplying the city with water directly for the reservoir if absolutely necessary.

The following items entered into the construction of reservoirs and filters.

Earth excavation	8 560 cubic yards
Rock excavation	1 050 „ „
Embankment and fill	5 800 „ „
Concrete	2 570 „ „
Steel reinforcement	275 000 lbs.
Steel I beams	135 000 „
Filter gravel	510 cubic yards
Filter sand	2 130 „ „

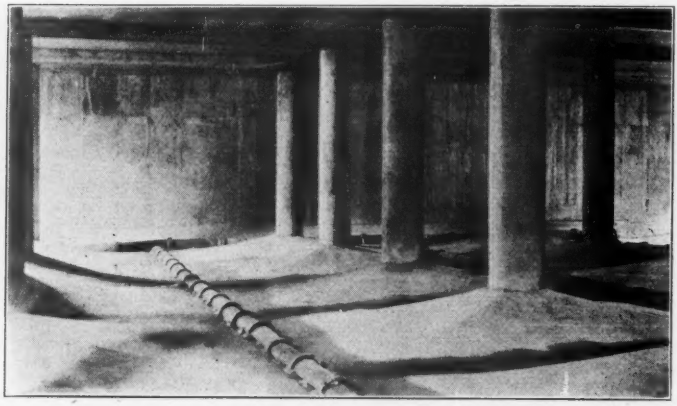


FIG. 4. — STONE DAM FILTER READY FOR FILTERING MATERIALS.

Practically all of the piping connections, including the 8-in. influent and effluent mains, the 16 and 14-in. connection between the Beech Hill Reservoir and the supply main to the city, a 12-in. temporary line from the temporary line above the filters to the Stone Dam, the 12-in. influent and effluent mains and the 10-in. filter drain, also many miscellaneous items of work, were performed by the Water Department under the direction of Col. Paul F. Babbidge, Superintendent.

Improvement in Fire Hydrant Service. As the result of the new constructions and the cleaning of mains the city now has available at Central Square under a pressure of 60 lbs. per sq. inch the following quantities of water.

	Gallons per Minute.
From Beech Hill Reservoir	2 800
From Stone Dam Filters	1 200
	4 000

These are to be compared with 1 500 gal. per min. formerly available. At 75 lbs. pressure 2 900 gal. per min. may be discharged at the Square.

The improvements were designed and the construction and operation of the works supervised by the writers. Mr. Thomas F. Dorsey was resident engineer during construction.

DISCUSSION.

DESMOND FITZGERALD.* May I ask what was the cost of this system?

MR. SAMPSON. The cost of the reservoir was $48 500, which is $32 500 per mil. gal.

The Beech Hill Filter cost $31 000, which is $41 500 per mil. gal., or $207 500 per acre.

The Stone Dam Filter cost $53 350, which is $35 500 per mil. gal., or $177 500 per acre.

The above costs include engineering and all other expenses except the outside piping connections which were installed by the city.

A. R. HATHAWAY†. Referring to the check valves; supposing they should open, would they allow unfiltered water to go to the city?

MR. SAMPSON. The only chance of that occurring would be when there was a serious fire in the city, in which case the Sylvan Lake supply would go into the city. But the Sylvan Lake supply is the best of the three sources, and has always been considered satisfactory.

HENRY A. SYMONDS.‡ Mr. President, I would like to ask Mr. Sampson if there is any tendency or possibility of water getting in under the floor of the filter in the reservoir, and if there was any need of consideration of the possible factor of an upward pressure? Secondly, what provision was made for making tight joints in the floor between the different days' work? And then I would like to ask also what the thickness of the concrete wall was at the reservoir?

MR. SAMPSON. In answer to the first question, Mr. Symonds, upward pressure was considered, but it was found that the weight of the groined arch floor, columns, roof, and earth cover on the roof, even without the filter sand in place, was sufficient to prevent the structure being lifted.

The avoidance of leakage from the Stone Dam reservoir into the filter, to prevent unfiltered water being delivered to the city, was accomplished by making the construction joints with deep grooves and by using especial care in cleaning and grouting just previous to placing the concrete on successive days. The filter was tested and found to be water-tight before the filtering material was placed.

Regarding the thickness of the reservoir wall; there were seven dif-

* Brookline, Mass.
† Water Registrar, Springfield, Mass.
‡ Consulting Engineer, Boston, Mass.

ferent rings, each 3 ft. in height; the bottom ring was 22 in. thick, and then each ring was successively 2 in. thinner, so that the top ring was 10 in.

MR. FITZGERALD. The concrete seems to be of very excellent quality, I should judge. Did you use the same kind of cement throughout?

MR. SAMPSON. I suggest that Mr. Sperry of Cambridge, the contractor, could better answer that question.

MR. SPERRY. We used the same kind of cement as long as we could obtain it in sufficient quantities. Then we used an imported cement, which we found even better than the American cement both for strength and for workability.

We washed the sand for concrete; we did not do this for the Beech Hill Filters, but we did in the reservoir and Stone Dam Filter. That gave additional strength; it was found that by washing the sand we got a strength of about fifty per cent. additional.

MR. SAMPSON. We had a good test of the Beech Hill Filter roof. I was up there one day last summer when they were placing sand in the filter. The roof was designed for a total dead and live load of about two hundred and fifty pounds per sq. ft. In addition to the 18 in. of earth cover they had loaded that roof with about five feet of filter sand over a large area. It should have collapsed, but it did not.

THE PRESIDENT. Where did the cement come from? And was the price any less on the imported cement?

MR. SPERRY. Why, it was a little bit more, but due to the contract we had they furnished it at the same price. Around Boston we could buy it a little bit less.

MR. SAMPSON. Where does it come from?

MR. SPERRY. Belgium.

PROF. RICHARD TYLER.* Mr. President, I would like to ask in regard to the difficulty of determining the cause of the epidemic. Was that merely a deduction by process of eliminating all other possible conjectures, or was there anything definite?

MR. WESTON. The evidence was largely circumstantial. We found an unusually large number of bacteria, which proved to be B. coli, — they were very active gas-forming bacteria. The other facts were simply incidental. Our opinion was that it was a concentration of organisms rather than a new occurrence of organisms. Looking over the results for several years, we found that almost every summer these gas-forming bacteria occurred in greater or less number. But Professor Whipple and we thought that the conditions which existed at the time of the epidemic, which were peculiar, brought an unusually large number of those bacteria in the stomachs of people.

The situation was very acute. Commercial travelers would come there and become immediately ill, after their first drink of water, almost.

* Massachusetts Institute of Technology, Cambridge, Mass.

MR. SAMPSON. There is one more thing that might be of interest and that is the cleaning of one of the supply mains.

The Beech Hill main, as Mr. Weston stated, was laid in 1886, and it had become so filled with incrustation or deposits, that its capacity was about fifty per cent. of what would be expected for a new pipe. So the city made a contract with the National Water Main Cleaning Company for cleaning out this main. Its length was three miles and they began early in April, so as to get it done before the Beech Hill Filters were in operation. In spite of topographical difficulties it took them only about a week to complete the work.

I think we rather put one over on them, though. We made a contract whereby they would accept a certain price (it isn't customary to give those prices, I find), they guaranteeing to deliver 95 per cent. of the original capacity of the main by Weston's tables. We made a very careful test after the main was cleaned, and found that the main actually delivered 81.7 per cent., and the flow was increased from about 364 to 635 gal. per minute. But on account of the percentage being 13.3 per cent. less than the guarantee, a clause in the contract was invoked whereby a certain amount per foot was deducted for every 5 per cent. that they did not come up to the 95 per cent.

I think they did a very good job, everything considered. And perhaps the most interesting part of the whole work was that they made about sixty-five joints, and they got more than enough lead out of that pipe to make all the joints. [*Laughter.*]

FRANK B. NORTHROP.* I would like to ask the name of that altitude valve.

MR. SAMPSON. Golden-Anderson double-acting automatic altitude valve.

MR. WESTON. The results of operation have been satisfactory, although the Stone Dam Filter, which was filled largely with beach sand, and

REMOVAL OF COLOR.

Date.	COLOR — PARTS PER MILLION.			
	BEECH HILL FILTERS.		STONE DAM FILTERS.	
	Influent.	Effluent.	Influent.	Effluent.
1925.				
December 29	35	25	35	30
December 30	22	20	22	20
1926.				
February 9	..	25	..	35
February 25	..	..	15	15
March 19	..	25	..	..

* Superintendent, Millbury and Grafton (Mass.) Water Companies, Millbury, Mass.

not placed in service until December 9, has not yet accumulated sufficient matter in the form of films about the sand particles to be as efficient as the usual sand filter, especially for the removal of color and bacteria.

The Beech Hill Filter, which contained proportionally more local bank sand and which was put in service before the fall overturn had occurred in the reservoirs, has more nearly approached the efficiency which may be expected later of both filters.

REMOVAL OF BACTERIA.

Date.	BACTERIA AT 37.5 DEGREES C.			
	BEECH HILL FILTERS.		STONE DAM FILTERS.	
	Influent.	Effluent.	Influent.	Effluent.
1925.				
December 30	38	13	38	3
1926.				
January 30	..	..	17	3
February 9	2 000	2	22	10*
February 9	..	9	..	5
February 25	7	8	11	6
March 9	32	2	39	2
March 11	7	2	15	40*
March 19	7	0	12	2*

*By New Hampshire State Board of Health.

No B. coli have been found in either raw or filtered water since the examinations began. Gas-forming bacteria have been found in the raw water, and soon after the filters were placed in service, these bacteria were found in the filtered water. However, none of these have been found in the Beech Hill Filter effluent since examinations were begun on December 29, nor in the Stone Dam Filter effluent since March 9.

The plant is operated by the Water Department, with the advice of the authors and with the coöperation of the laboratory of the State Board of Health.

THE ECONOMY OF MUNICIPAL BONDS FOR WATER WORKS CONSTRUCTION.

BY CHARLES W. SHERMAN.*

[*Read January 12, 1926.*]

The object of this paper is to show that in some cases it is true economy to borrow money for the construction of large items of municipal water-works construction, rather than to attempt to pay for them outright.

This appears to be in opposition to the pay-as-you-go policy now urged so strongly upon our cities and towns. It is not really in opposition to that policy, for, as will be shown later, the economy claimed can be obtained only in cases where the amount of money borrowed is not excessive in proportion to the ability of the municipality; and when interest, debt charges, and ordinary expenses are promptly paid. In other words, the pay-as-you-go policy must be generally followed, or bonding becomes uneconomical.

The pay-as-you-go policy is the only sound one in so far as it relates to ordinary expenses of maintenance and operation, and the comparatively minor expenses of renewals and small extensions which are required with practical regularity in all growing towns. Such expenses demand approximately uniform amounts from year to year, and can readily be covered in the water rates without the necessity of making frequent changes in the rate base. The policy of borrowing money for major extensions or large items of work is, however, not only absolutely necessary, because the funds required could not practically be raised all at once by any equitable method; but it is not necessarily, or even generally, wasteful or uneconomical. On the contrary, in most cases it will result in an actual saving of money.

We sometimes hear the comment that it is a great waste for our municipalities to borrow large sums of money for considerable terms of years, thus necessitating total payments amounting in some cases to 150 per cent. or more of the cost of the works. This idea is based, probably unconsciously, on the old impression that it was unmoral to charge interest for the use of money. It is, of course, an axiom that money is entitled to proper rental, or interest, just as much as services or property. As a consequence, it is necessarily true that payment in cash for anything involves the loss in perpetuity of the interest upon the money spent.

There are two ways of considering an expenditure; one, the cost in cash outlay at the time of purchase; the other, the loss of annual interest which the cash paid would produce if properly invested. An item costing $100 000

* Of Metcalf & Eddy, Consulting Engineers, Boston, Mass.

may equally fairly be considered to represent an annual cost of $4 000 for all time, if the interest rate be assumed as 4 per cent.

A true comparison of relative costs resulting from different methods of payment can best be made by computing the *present worths* of all the sums of money paid or to be paid by the different methods considered. In such computations, it is essential for fair comparison to use the proper rates of interest, which are not necessarily identical throughout the computation.

For example, let us take an item of plant costing $100 000. If the money were available in the treasury, it could be paid for in cash and the cost would obviously be $100 000. If the money were not in hand, it would be necessary to obtain it, either from the citizens or water takers by some form of tax or assessment, or to borrow money under one of three methods, namely: (*a*) without definite provision for repayment of bonds, assuming that they will be refunded at maturity; (*b*) with provision for a sinking fund adequate to repay the bonds at maturity; (*c*) with provision for serial payments by which the bonds are repaid from time to time during the period covered by the loan.

The first method, in which no definite arrangement is made for repayment of bonds, practically assumes that the bonds will run forever. The only annual payment required is that of interest. In this discussion, we are not particularly concerned whether the life of the plant for the construction of which the bonds are issued is finite or infinite; the credit of the municipality is the security on the bonds, and not the plant. Assuming 4 per cent. as the fair rate of interest upon municipal bonds, an annual payment of $4 000 will be required. The works have cost $100 000, but this has not been paid by the municipality which has elected to pay an annual charge of $4 000 instead. The present worth of an annual payment of $4 000 in perpetuity is $100 000. Mathematically, the sum of money eventually to be paid by the town is infinitely large, but actually the cost is the present worth of the annual interest, which is the same sum that would have been paid in cash if no bonds had been issued.

In case of a bond issue for a term of years, with provision for a sinking fund by which the bonds are to be paid at maturity, the condition is similar except that the annual payment is greater and extends over a limited time. At least, that is the case when the earnings of the sinking fund are at the same rate as the interest paid upon the bonds. In general, this is approximately true. Sinking funds can seldom be invested with the degree of security required for such funds at a higher average rate than is paid on the best municipal bonds. It is, therefore, fair to assume that the sinking fund will accumulate interest at the same rate as that paid, assumed in this study as 4 per cent.

For example, let us assume bonds running 25 years; the annual payment of interest will be $4 000 and the annual contribution to the sinking fund will be $2 401.20. The total annual payment required during the 25 years will then be $6 401.20, and the total sum of money paid out by the munici-

pality will be $160 030. This does not mean that the works will have cost this sum of money, any more than they cost an infinite sum in the case of bonds which are refunded as they mature and on which the interest goes on forever. The total payment eventually amounts to this sum, but $60 030 of it will have been paid as interest or rental for the use of money furnished and not for the works. A similar condition exists in a sinking fund for any other term of years, the only essential difference being in the amount of the annual payment. If the term is short, the amount to be paid annually is comparatively high; if the term is long, the annual payment may be little more than the amount of the interest upon the bonds. This latter item will, however, remain unchanged during the period of payment. Whatever the term and whatever the total annual payment and the gross cumulative amount, the present worth of all the payments will be $100 000, and the real cost to the municipality is this sum and no more.

Obviously, it is not public policy to allow municipal bonds to run for an indefinite period, and some method of providing for their repayment must be adopted. Theoretically, the sinking fund method is usually the most advantageous, in that it is least burdensome to the municipality of any practical arrangement. The total amount of annual payment is uniform throughout the term of the bonds, and if this term is moderately long the amount is not usually excessive or especially burdensome in the rates. Practically, the sinking fund method has proven objectionable because of occasional cases of dishonesty in the administration of sinking funds, and the far more frequent cases of financial incompetence or poor judgment on the part of sinking fund trustees, with resulting losses which have had to be met by refunding bonds and by excess costs which have increased the burden upon the community. The sinking fund method of paying municipal bonds is no longer legal in Massachusetts.

The remaining method of financing such bonds is by serial payments. The present Massachusetts general laws require that municipal bonds be redeemed by annual payments, generally beginning the year after the issuance of the bonds, and that no such payment in any year shall be less than in any subsequent year. In other words, the burden of annual charges must necessarily be greatest in the first years, when presumably the income from the utility is least and it is most burdensome to meet these charges. A method by which the total annual payments of interest and maturing bonds may be substantially equalized — so that in the earlier years the payment will consist mainly of interest with a small payment upon the bonds, and in later years, when the interest payment is reduced as the amount of outstanding bonds grows less, the annual payments for retirement of bonds are correspondingly increased — has much to recommend it. However, it is not legal in Massachusetts for municipal bonds and will not be further discussed in this paper.

It has been shown that with the value of money taken as fixed by the rate of interest paid on the bonds, the present worth of all the payments to

PRESENT WORTH AT 6% INTEREST OF ANNUAL PAYMENTS REQUIRED UPON $100 000 OF SERIAL BONDS ISSUED AT 4% INTEREST, FOR VARIOUS TERMS OF YEARS.

10-Year Term.

Year.	Repayment of Principal.	Interest.	Total Annual Payment.	Balance Outstanding.	Present Worth of Annual Payment at 6%.
0	.....	.....	.....	$100 000	.....
1	$10 000	$4 000	$14 000	90 000	$13 208
2	10 000	3 600	13 600	80 000	12 104
3	10 000	3 200	13 200	70 000	11 083
4	10 000	2 800	12 800	60 000	10 139
5	10 000	2 400	12 400	50 000	9 266
6	10 000	2 000	12 000	40 000	8 460
7	10 000	1 600	11 600	30 000	7 715
8	10 000	1 200	11 200	20 000	7 027
9	10 000	800	10 800	10 000	6 392
10	10 000	400	10 400	0	5 807
	$100 000	$22 000	$122 000		$91 201

15-Year Term.

0	.....	.....	.....	$100 000	.....
1	$7 000	$4 000	$11 000	93 000	$10 377
2	7 000	3 720	10 720	86 000	9 541
3	7 000	3 440	10 440	79 000	8 766
4	7 000	3 160	10 160	72 000	8 048
5	7 000	2 880	9 880	65 000	7 383
6	7 000	2 600	9 600	58 000	6 768
7	7 000	2 320	9 320	51 000	6 198
8	7 000	2 040	9 040	44 000	5 672
9	7 000	1 760	8 760	37 000	5 185
10	7 000	1 480	8 480	30 000	4 735
11	6 000	1 200	7 200	24 000	3 793
12	6 000	960	6 960	18 000	3 459
13	6 000	720	6 720	12 000	3 151
14	6 000	480	6 480	6 000	2 866
15	6 000	240	6 240	0	2 604
	$100 000	$31 000	$131 000		$88 546

20-Year Term.

0	.....	.....	.....	$100 000	.....
1	$5 000	$4 000	$9 000	95 000	$8 491
2	5 000	3 800	8 800	90 000	7 832
3	5 000	3 600	8 600	85 000	7 221
4	5 000	3 400	8 400	80 000	6 654
5	5 000	3 200	8 200	75 000	6 128
6	5 000	3 000	8 000	70 000	5 640
7	5 000	2 800	7 800	65 000	5 188
8	5 000	2 600	7 600	60 000	4 768
9	5 000	2 400	7 400	55 000	4 380
10	5 000	2 200	7 200	50 000	4 021
11	5 000	2 000	7 000	45 000	3 688
12	5 000	1 800	6 800	40 000	3 379
13	5 000	1 600	6 600	35 000	3 094
14	5 000	1 400	6 400	30 000	2 831
15	5 000	1 200	6 200	25 000	2 587
16	5 000	1 000	6 000	20 000	2 362
17	5 000	800	5 800	15 000	2 154
18	5 000	600	5 600	10 000	1 962
19	5 000	400	5 400	5 000	1 785
20	5 000	200	5 200	0	1 621
	$100 000	$42 000	$142 000		$85 786

PRESENT WORTH AT 6% INTEREST OF ANNUAL PAYMENTS REQUIRED UPON $100 000 OF SERIAL BONDS ISSUED AT 4% INTEREST, FOR VARIOUS TERMS OF YEARS.

25-Year Term.

Year.	Repayment of Principal.	Interest.	Total Annual Payment.	Balance Outstanding.	Present Worth of Annual Payment at 6%.
0	.....	.....	.....	$100 000	.....
1	$4 000	$4 000	$8 000	96 000	$7 547
2	4 000	3 840	7 840	92 000	6 978
3	4 000	3 680	7 680	88 000	6 448
4	4 000	3 520	7 520	84 000	5 957
5	4 000	3 360	7 360	80 000	5 500
6	4 000	3 200	7 200	76 000	5 076
7	4 000	3 040	7 040	72 000	4 682
8	4 000	2 880	6 880	68 000	4 317
9	4 000	2 720	6 720	64 000	3 978
10	4 000	2 560	6 560	60 000	3 663
11	4 000	2 400	6 400	56 000	3 371
12	4 000	2 240	6 240	52 000	3 101
13	4 000	2 080	6 080	48 000	2 850
14	4 000	1 920	5 920	44 000	2 618
15	4 000	1 760	5 760	40 000	2 403
16	4 000	1 600	5 600	36 000	2 204
17	4 000	1 440	5 440	32 000	2 020
18	4 000	1 280	5 280	28 000	1 850
19	4 000	1 120	5 120	24 000	1 692
20	4 000	960	4 960	20 000	1 547
21	4 000	800	4 800	16 000	1 412
22	4 000	640	4 640	12 000	1 288
23	4 000	480	4 480	8 000	1 173
24	4 000	320	4 320	4 000	1 067
25	4 000	160	4 160	0	969
	$100 000	$52 000	$152 000		$83 711

30-Year Term.

0	.....	.....	.....	$100 000	.....
1	$4 000	$4 000	$8 000	96 000	$7 547
2	4 000	3 840	7 840	92 000	6 978
3	4 000	3 680	7 680	88 000	6 448
4	4 000	3 520	7 520	84 000	5 957
5	4 000	3 360	7 360	80 000	5 500
6	4 000	3 200	7 200	76 000	5 076
7	4 000	3 040	7 040	72 000	4 682
8	4 000	2 880	6 880	68 000	4 317
9	4 000	2 720	6 720	64 000	3 978
10	4 000	2 560	6 560	60 000	3 663
11	3 000	2 400	5 400	57 000	2 845
12	3 000	2 280	5 280	54 000	2 624
13	3 000	2 160	5 160	51 000	2 419
14	3 000	2 040	5 040	48 000	2 229
15	3 000	1 920	4 920	45 000	2 053
16	3 000	1 800	4 800	42 000	1 890
17	3 000	1 680	4 680	39 000	1 738
18	3 000	1 560	4 560	26 000	1 598
19	3 000	1 440	4 440	33 000	1 467
20	3 000	1 320	4 320	30 000	1 347
21	3 000	1 200	4 200	27 000	1 235
22	3 000	1 080	4 080	24 000	1 132
23	3 000	960	3 960	21 000	1 037
24	3 000	840	3 840	18 000	948
25	3 000	720	3 720	15 000	867
26	3 000	600	3 600	12 000	791
27	3 000	480	3 480	9 000	722
28	3 000	360	3 360	6 000	657
29	3 000	240	3 240	3 000	598
30	3 000	120	3 120	0	543
	$100 000	$58 000	$158 000		$82 886

be made upon sinking fund bonds is equal to the face of the bonds. As a matter of fact, however, the value of money ought to be taken in such comparison on the basis of its value to the people from whom the money is obtained; that is to say, to the citizens who pay the taxes, water rates, or assessments from which the funds are derived. If the money so taken from the citizens were left in their hands and put in savings banks its value would probably be a fraction of a per cent. greater than the rate paid on municipal bonds. If, however, the money were to be raised by the city outright, by special assessment of considerable magnitude, many of the citizens might have to obtain the funds to meet such an assessment through mortgages upon their homes or borrowing on collateral, for which, under circumstances as they exist today, they could hardly expect to pay less than 6 per cent. This is believed to be a fairer basis for estimating the value of money as raised by the community for paying charges upon its debts or for payment for construction outright. A comparison of the present worth of money at 6 per cent., when 4 per cent. rate is paid upon the municipal bonds, is therefore believed to be most significant as indicating the real cost to the community.

In the case above assumed in which sinking fund bonds are issued for a term of 25 years, the annual payment required would be $6 401.20. The present worth of 25 annual payments of this amount, computed at 6 per cent., is found to be $79 769.70. This is less than the cash cost of the works by upwards of $20 000, and indicates that the community, in the person of its citizens, really saves this amount of money by issuing bonds rather than by paying cash for the construction assumed.

Somewhat different amounts of saving would result if the term of years for which the bonds were to run were varied, but the single example is sufficient for illustration, particularly in discussing Massachusetts conditions where sinking fund bonds cannot be issued.

Conditions are similar in the case of serial bonds, except that the mathematical computation is a little more laborious because the annual payments vary from year to year. If the value of money be taken as 4 per cent., the same rate as is paid on the bonds, the present worth of all the sums to be paid will be found in each case to be $100 000. In other words, under such circumstances, it is just as economical to borrow money as to pay in cash. If, however, the value of the money to the citizen be considered as in the example above, and 6 per cent. be assumed as a fair rate, there will always be a saving from the issuance of bonds, and the total amount of the saving will be greater the longer the term of the bonds.

The tables appended show the present worth of each of the annual payments required to meet a $100 000 loan when the bonds are issued for terms of 10, 15, 20, 25, and 30 years. The total saving in the case of the 10-year bonds is approximately $9 000; of the 15-year bonds, $11 500; of the 20-year bonds, $14 000; of the 25-year bonds, $16 500; and of the 30-year bonds, $17 000.

The fluctuations are not altogether uniform because the annual payment of principal required varies in case the amount of money borrowed is not exactly divisible by the number of years the bonds are to run, and the practical necessity of issuing the bonds in $1 000 denominations. The results of a computation for a bond issue of $200 000 would not be exactly proportional to those for $100 000 in some cases for this reason.

At the beginning of this paper, attention was called to the fact that the economic saving shown by the computations must not be assumed to prove that all municipal expenditures should be bonded, instead of adopting the pay-as-you-go policy in so far as it can be done without involving too much fluctuation in the annual amounts to be paid. As a matter of fact, a little reflection will show that the economy shown is dependent absolutely upon the differential between the cost of money to the municipality and its value to the individual. The possible saving is predicated upon the assumption that the credit of the municipality is of the best. This condition will only exist when the total bonded indebtedness is small in proportion to the value of property and to the dependable income of the municipality, when its record for the prompt payment of its obligations is satisfactory, and when it is meeting all ordinary expenses out of revenue. An attempt to follow any other course would affect its credit to such extent that it would no longer be possible to borrow money on favorable terms, and it is conceivable that ultimately the rate to be paid by the municipality would exceed the value of money to the individual, in which case exactly opposite results would be shown from those indicated above.

FINANCING MAIN PIPE EXTENSIONS BY THE ASSESSMENT METHOD.

DISCUSSION OF PAPER PRESENTED BY CALEB MILLS SAVILLE.

[This paper was printed in the September, 1925, JOURNAL, page 185. — EDITOR.]

G. A. ELLIOTT.* It may be of interest to speak of the methods of financing main pipe extensions used by some of the "privately owned" or public utility water works, who can not make use of the assessing powers inherent in municipalities or political districts. The Spring Valley Water Company, which supplies San Francisco with water, has two rules under which it operates for pipe extensions other than those installed by the Company, without request, in the normal growth of the distributing system.

In framing these rules which have been in successful use for about four years, it was recognized that requests for extensions would generally fall into one of two classes: first, for mains to be laid in streets within the built-up sections of the city, where for some reason a few blocks had been held without improvement, in which it was reasonable to expect rapid construction of houses when opened for settlement; and second, tracts of land on the outer unsettled portions of the community where development by real estate agents might not be followed for years by sufficient settlement to return, through the water rates, even the interest on the cost of the distributing pipe, to say nothing of a proportion of the general operating costs of the system.

To meet these two cases the following rules were put into effect:

1. The Company shall specify sizes, character and location of all pipes and appurtenances for new services and shall perform the work of construction.

It is understood that where extensions are to be made from feeder lines already installed in the district, the maximum deposit required from the consumer to cover the cost of the extension will be based on the cost of four-inch cast iron pipe.

2. In subdivisions or in districts where a system of feeder lines and laterals must be installed to furnish the service desired, the applicant or applicants for such service will be required to deposit the estimated cost of the complete system.

3. If the estimated cost of such pipe extension for new service is not in excess of four times the estimated immediate annual revenue† therefrom the Company will make such installation at its own expense. The Company reserves the right to refuse to make any extension at its own expense if it is not satisfied that it will be put to immediate and permanent use.

4. If the estimated cost of such extension for new service is in excess of four times the estimated annual revenue therefrom the Company will

* Chief Engineer, Spring Valley Water Company.

† The term "estimated immediate annual revenue" is to apply to houses under construction by the applicant at the time of making the application and to houses already occupied and which will be connected to the new extension.

make the installation, provided the applicant deposits with the Company the estimated amount of such cost in excess of four times the estimated immediate annual revenue, adjustment of any difference between the estimated and actual cost to be made at the completion of the installation. The Company will thereafter refund to the applicant, until the amount of the deposit has been returned, four times the amount of revenue collected annually from the permanent new consumers attached to this extension:

Provided, however, that if additional consumers, other than those contemplated in the original application, are connected to such extension, they shall be required, upon demand by the original depositor, to pay to the Company their pro rata of the cost of the extension, proportional refund to be made by the Company to the original depositor.

5. When the extension of mains for new services are made under the above rules, the necessary active services and meters will be installed at the Company's expense.

The San Jose Water Works, supplying San Jose, California, makes use of the following rule in making extensions into territory where an immediate revenue commensurate with the cost of the mains is not probable:

No. 20. *Water Main Extensions.* The Company will extend its water distribution main to new consumers at its own expense when the total length of main required is not in excess of 100 ft. per consumer.

If the total length of main required is in excess of 100 ft. per consumer, the consumer or consumers to be served will be required to advance that portion of the cost of such extension over and above the cost of the equivalent of 100 ft. of main per consumer, and the money so advanced will be refunded in amounts equal to the cost of a 100-ft. extension, such as would normally be made free for each additional consumer whose service shall be taken off the first extension within a period of ten years for bona fide applicants from the making of the first extension, but in no case shall the refund exceed the original deposit.

Water main extensions may be made by special arrangement, under the guarantee of definite minimum payments and upon private property under good and sufficient rights of way, subject to the general rules and regulations of the Railroad Commission of the State of California in the territory where that Commission has jurisdiction.

No. 20A. *Water Main Extensions for Real Estate Subdivisions.* In case the utility is asked to pipe a real estate subdivision, the estimated cost of the pipe facilities, including fittings and valves, plus 10 per cent. of the actual cost of labor and material for general overhead, shall be advanced by the applicant for service. The amount so advanced will be refunded to the applicant by the utility when the revenue from the sales of water through this pipe system in any twelve consecutive months shall equal 25 per cent. of the sum of the actual cost of the pipe system, including overhead, plus the cost of such meters and services as have been installed by the utility. No refunds will be made after a period of seven years shall have elapsed.

At the completion of the work of installing the pipe system in a real estate subdivision, the amount deposited shall be adjusted so that the applicant for service shall have advanced the actual cost of labor and material, plus 10 per cent. for overhead. Such an adjustment may result in a cash rebate by the utility to the applicant, or the payment by the applicant of an additional sum to the utility.

A FINENESS MODULUS FOR FILTER SANDS.

DISCUSSION OF PAPER PRESENTED BY RICHARD G. TYLER.

[This paper was printed in the September, 1925, JOURNAL, page 239. — EDITOR.]

RICHARD G. TYLER. The writer has read with interest the various discussions of his paper on "Fineness Modulus for Filter Sands," which discussions have brought out additional information on the behavior of the sand in filters. Some of the points discussed seem to warrant further comment.

Professor Saville calls attention to the fact that only one of the sands tested was a filter sand. The reason for this was, that it seemed desirable in making permeability tests to use arbitrary gradings covering a wide range, both as to effective size and uniformity coefficient. Filter sands do not allow a large enough variation in these factors to make this study general in character, so that any formula derived would be applicable to the various problems of permeability of sands; for example, the sands to be considered in studies of underground sources of water would be very different in character from filter sands.

Attention was called to the fact that the conclusions reached were tentative in character, since only about fifty tests were made on ten different sands, and that additional tests would undoubtedly modify the coefficients and exponents proposed. It is believed, however, that one definite conclusion may be drawn when Professor Saville's data are also considered, and that is that the fineness modulus does not give a sensitive measure of the permeability of sands. This can be seen from Saville's formula

$$V = 0.618\ h(FM)^{4.9}$$

where V varies about as the fifth power of the fineness modulus, so that a slight error in the latter which might result from different methods of screening, or the failure to use sieves standardized by the same method, would make a very large error in permeability.

The writer is grateful to Professor Saville for pointing out inaccuracies in Column 8, Table 2. These values were not computed by the formula, but were taken from a chart not included in the paper. The conversion factor 439.2 should be used to convert values of V into meters per day, if one wishes to compare results with those of the Hazen formula. The unit used by the writer was in feet per minute since it was thought that this unit could be more easily visualized by the layman.

In regard to the relationship existing between surface modulus and surface area for a given weight of sand, if we assume that all sand particles

are spheres of diameters equal to the various sieve openings, this may be seen from the following formulas:

$$\text{Surface modulus} = P_1 + \frac{P_2}{i} + \frac{P_3}{i^2} + \ \ldots\ . \ \frac{P^n}{i^{n-1}}$$

where i equals sieve interval and other quantities are as in original paper.

$$\text{Surface area} = \frac{0.02264}{d_1}\left(P_1 + \frac{P_2}{i} + \frac{P_3}{i^2} + \ \ldots\ . \ \frac{P^n}{i^{n-1}}\right) \text{ sq. cms.}$$

where $\frac{0.02264}{d_1}$ equals $\frac{\text{surface area}}{100}$ of one gram of spheres of diameter d_1 which is the diameter in cm. of that smallest size particle of which P_1 represents the percentage.

The assumption that sand grains are spherical is not accurate and the surface areas of various sands of equal grain size vary considerably, but until some method has been devised for determining the actual surface area, these discrepancies must be taken care of by the use of a coefficient.

The most serious objection which the writer encounters in using either the surface modulus or the surface area as recommended by him, is that the sieve analysis does not give a measure of the actual surface area in a unit volume of the material. These quantities are given for a unit weight of the sand and a varying percentage of voids affects the result obtained. It would appear to be necessary to take the percentage of voids into account, and an attempt was made in these tests to do so, but it was not possible with the apparatus used to determine the porosity of the material under test conditions. The results reported in Column 4, Table 2, were obtained from tests on samples using similar methods of compaction, but do not represent the voids in the sand during the test. The writer has since learned that European investigators have used the term "specific surface" to indicate the total surface area per unit of volume of the sand. This term would appear to satisfactorily combine the results of the sieve analysis and the porosity of the material and would, therefore, be a better term to use than fineness modulus in the formula which has been suggested. Surface modulus can be converted into specific surface by inserting a factor based upon the percentage of voids. This criticism, in regard to failure to take into account the compactness of sand, applies with equal force to the Hazen formula.

Mr. Hansen mentions the method of expressing the results of the sieve analysis used at St. Louis and Baltimore, which is described more in detail in a recent Committee Report of the American Water Works Association.[10] This method is based upon an attempt to take into account the stratification of the sand which occurs in the filter, and a graph is prepared indicating the depth of each size of material, based upon a complete separation as given by the sieve analysis. In considering this method from the standpoint of determination of permeability of the filter, it is thought that it has no apparent advantage over methods now in use, except perhaps to

make it easier to visualize something of what takes place in the filter. It does not appear, however, that the separation which occurs in the filter is nearly as complete as would be indicated by this graph, but such stratification as does take place could be taken into account in applying a formula, by varying the factor representing the percentage of voids with its corresponding change in depth of the sand in the filter. These variables would be indicated by a change in the specific surface. Tests in the laboratory indicate that when a filter is washed, while some of the fine material is carried to the surface, what actually takes place in the sand bed is much more complex than this. The material, both coarse and fine, is carried to the surface locally, while in other parts of the bed there is a downward movement so that this circulation prevents the complete separation, such as is obtained by the sieve analysis. Anyone who has tried to use a sand containing too much fine material, with the hope of being able to flush this material to the surface where it can be removed, knows that a considerable amount remains in the sand for a long period and causes difficulty in operation of the filter.

It might be of interest in this connection to describe a test recently made in the laboratory. Two samples of a given sand of equal weight were taken; one, sample (a), was screened and separated out into the various sizes, while the other, sample (b), was tested in its unscreened state. Sample (b) was placed in a glass container so arranged that the wash water could be admitted uniformly through the bottom, and was washed according to accepted methods. As the vertical velocity of the water increased, the finer materials began to flush to the surface, but after a given velocity had been reached the water broke through at two points so that the vertical system of circulation, above mentioned, was set up at these points, while washing practically ceased in the rest of the filter. As the sand was flushed to the top, a column of sand moved downward alongside this area to take its place, so that all further sorting into sizes not only stopped, but the material already sorted was re-mixed in the manner stated. During this process there was an increase in volume of about five per cent., indicating that some segregation did take place.

Sample (a) was placed in the container in layers running from the coarsest material on the bottom to the finest on top. As washing began, the lower materials were undisturbed, but as soon as the vertical velocity of the water in the voids of the sand reached the critical velocity for each successive diameter of sand grain, these materials were lifted and mixed with those above them which had been lifted at a still lower velocity. As the velocity of wash was increased, this mixing affected the sand to still greater depths. The critical velocity above referred to could not be determined with accuracy, though it probably is a function of the smallest opening between sand grains and therefore a function of the diameter. This is much greater than the vertical velocity of the water above the filter, since the cross-section of flow is considerably less. Any materials of sufficient

fineness to be lifted by the much lower vertical velocity above the filter, were kept in suspension and settled on top of filter after washing, while other materials down to the lowest depth moved by the wash water were mixed together rather than sorted in sizes.

From this study, the importance of building up the velocity of wash gradually is quite evident. When this velocity was applied suddenly, the wash water broke through at several points as described in sample (b), while with a very gradual application it was possible to wash the finer surface materials without disturbing the materials at a greater depth. When it is possible to locate strainers by the greater agitation directly over them, the water is breaking through locally and not washing all the sand.

The Terzaghi formula for permeability of sands takes into account the percentage of voids, though it is also based upon the effective size. The formula is as follows:

$$k = \left(\frac{C}{V_o}\right)\left(\frac{V_o}{V_t}\right)\left(\frac{n-0.13}{\sqrt[3]{1-n}}\right)^2 d^2 \quad \text{(See reference [11])}$$

where $\frac{C}{V_o}$ = coefficient varying from 460 to 800.

V_o = coefficient of viscosity of water at 10° C.

V_t = coefficient of viscosity of water at test temperature.

n = percentage of voids.

d = effective diameter in cm.

k = coefficient of permeability in cu. cm. per sq. cm. per second, and represents the velocity of percolation under a hydraulic head of unity.

Mr. Catlett has raised an interesting question as to the function of a filter sand, and the writer agrees with his general conclusions. The division of the sand into two layers, covered by separate specifications, would appear to be satisfactory so long as the sand remained in its proper place. The stirring action which takes place during washing would probably cause a certain amount of mixing, which might produce a situation quite different from that which had been anticipated, both as to effective size of the top layer and as to total depth of materials. Such an arrangement would suggest the use of a sand with a larger uniformity coefficient for the lower layer, which would be quite different from present practice. A sufficient depth would be required to prevent breaking through under high rates or high heads. These suggestions, of course, apply only to rapid sand filters.

If, however, the conditions in a filter during the wash are similar to those in the above-mentioned experiment, it is probable that so much inter-mixing of the two layers of materials would take place that this method of specifying sands for filters would be impracticable.

The Committee Report[10], above referred to, brings out the interesting point that effective size and uniformity coefficient as obtained at different laboratories for a given sand sample, vary between wide limits. While this is due in part to lack of standardization of sieves, it is probably due also to

differences both in methods of testing and of plotting the data. The test reported from the Massachusetts Institute of Technology was run by the Cement Testing Laboratory, using the same sieve series and methods which they use for testing concrete aggregates. The high figure obtained for effective size appears to have been largely due to the fact that the material was shaken in the Ro-tap for only three minutes. The time element is particularly important where the sand is retained on relatively few sieves, as is the case with a filter sand. A later test run by the same laboratory, using a different set of sieves and a time of ten minutes, gave an effective size of 0.39 mm. and a uniformity coefficient of 1.37 as against 0.425 mm. and 1.32 respectively, as found by Mr. Hansen for this second sample. Some of the variations reported from the various laboratories can be accounted for by personal factors entering into the plotting of the data. Appreciable differences in effective size may be obtained by a single investigator when plotting results of sieve analyses on different kinds of graph paper. A little experimenting will suffice to convince one of this fact and indicate the probable errors introduced when the same data are plotted by different individuals on different kinds of paper. While these variations decrease with a smaller sieve interval, it seems illogical to use such extreme care in making the analysis and not be able to extend the same degree of accuracy to the use and interpretation of the data. While the necessity of standardizing sieves cannot be too strongly stressed, the writer feels that a method which permits inaccuracies such as above mentioned, is open to criticism and that a direct method of applying the data from the tests such as would largely eliminate the personal equation would be advantageous. The use of the specific surface or surface modulus instead of effective size and uniformity coefficient would have this advantage.

The writer wishes to reiterate that the Hazen formula has served a most useful purpose in the development of our present knowledge of the behavior of sands, but with the additional light that has been thrown on this problem by the investigations of Terzaghi and others, it seems that the principal justification for a continued use of the term "effective size" is in filters where the finer material (whether 10 per cent. or not has not yet been determined) is flushed to the surface of the bed by washing and is the effective part of the bed so far as filtration is concerned. In determinations of flow of underground waters, the use of effective size would not have this justification.

It is hoped that some light may be thrown upon the effect of segregation in the filter by tests which we are now carrying on through the courtesy and coöperation of the officials of the Cambridge Filter Plant. Our present investigations also include a study of the relationship of capillarity and permeability of sands, with an attempt to use the former, which is more easily determined, for finding the value of the latter. These investigations have not proceeded far enough to warrant further mention at this time

REFERENCES.

[10] Progress Report of Committee No. 18 on Filter Sand Testing and Recording, A. W. W. A. J., Vol. xiv, p. 235.

[11] *Engineering News-Record*, Vol. xcv, p. 832, November 19, 1925.

THE FIRE WHICH DESTROYED THE OFFICE AND SHOP OF THE FAIRHAVEN WATER CO.

BY HENRY T. GIDLEY.*

[*Read December 8, 1925.*]

About 12.20 on the morning of October 24, a fire broke out in Major Casey's boat shop, a large three-story frame building at the foot of Bridge Street in Fairhaven, Mass. Just east of the boat shop was a small one-story building used by the Fairhaven Water Company for an office and workshop (see Fig. 1). These two buildings were such roaring furnaces when the firemen arrived that nothing was saved from either building.

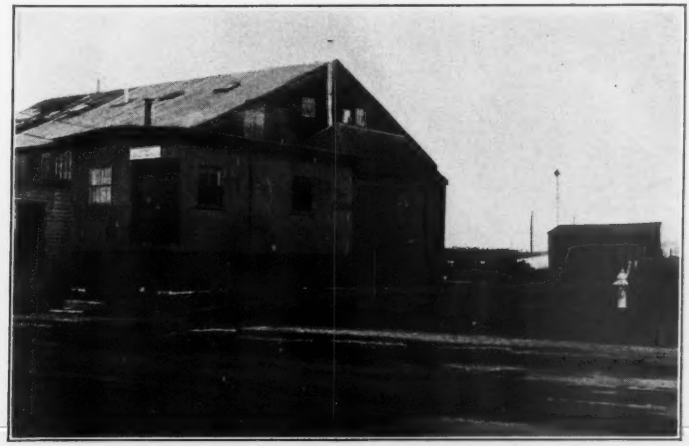


FIG. 1. — OFFICE OF FAIRHAVEN WATER COMPANY (before fire).

As the boat shop was on the water front, and as the wind was at the time of the fire from the northwest, the whole town was threatened. An alarm was rung in at New Bedford soon after the Fairhaven alarm, and two pumpers were sent over the river to help out the local department. The LaFrance pumper of the Fairhaven Fire Department, together with the two pumpers from the city of New Bedford, did great work in controlling the blaze, as it was under control by 2.30 A.M.

The roofs of many buildings in the vicinity caught fire, but were promptly looked after by the firemen or by the owners, so that no serious fire resulted, although fires started at least two blocks away. Two other houses were damaged in the section where the fire broke out. One was a

*Superintendent, Fairhaven, Mass., Water Co.

cottage across the street from the Water Company office, which was badly burned over the whole front. A cottage in the next lot east of the Water Company's lot had the roof burned off and the west side was badly burned.

There were many boats in the boat shop which were entirely destroyed, besides a number of valuable boats in the yard which had just been hauled out for the winter. Many of the latter were very much damaged (see Fig. 2).

In the Water Company repair shop the fire was so hot that the tools were a total loss. New meters on the shelves were burned up as though they were made of cardboard (see Fig. 3). The B. Lable Securities safe, however, which contained all the records, stood up remarkably well under such intense heat, and although it was red-hot for some time, nothing contained therein was the least bit damaged. In fact, the drawers and shelves were removed from the old safe and placed in the new safe without the least trouble.

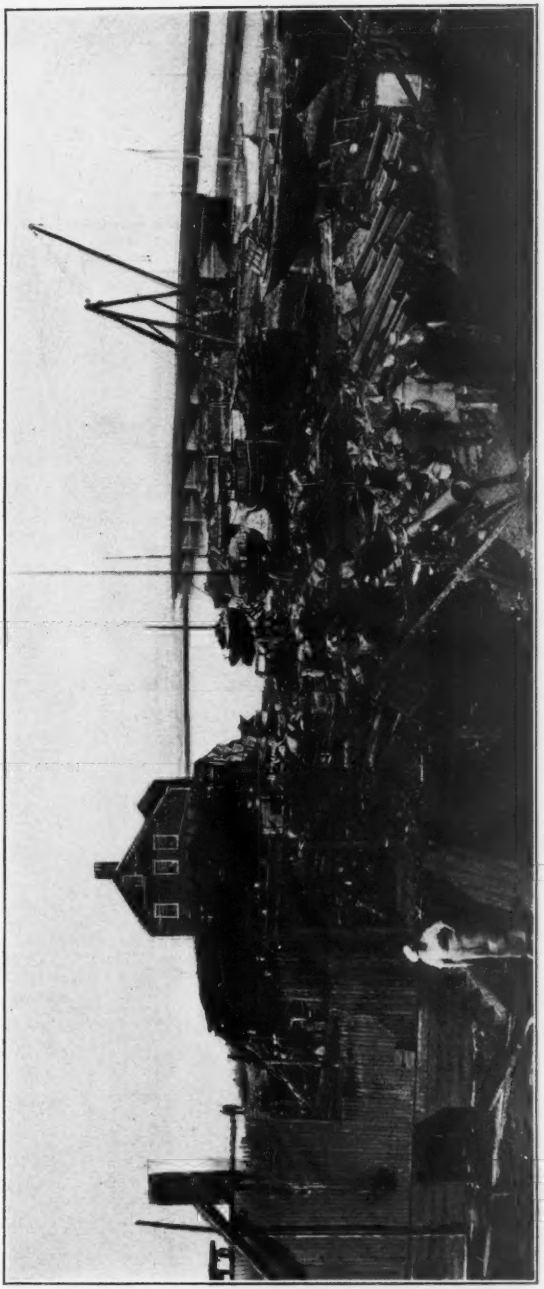


FIG. 2. — RESULTS OF FIRE.

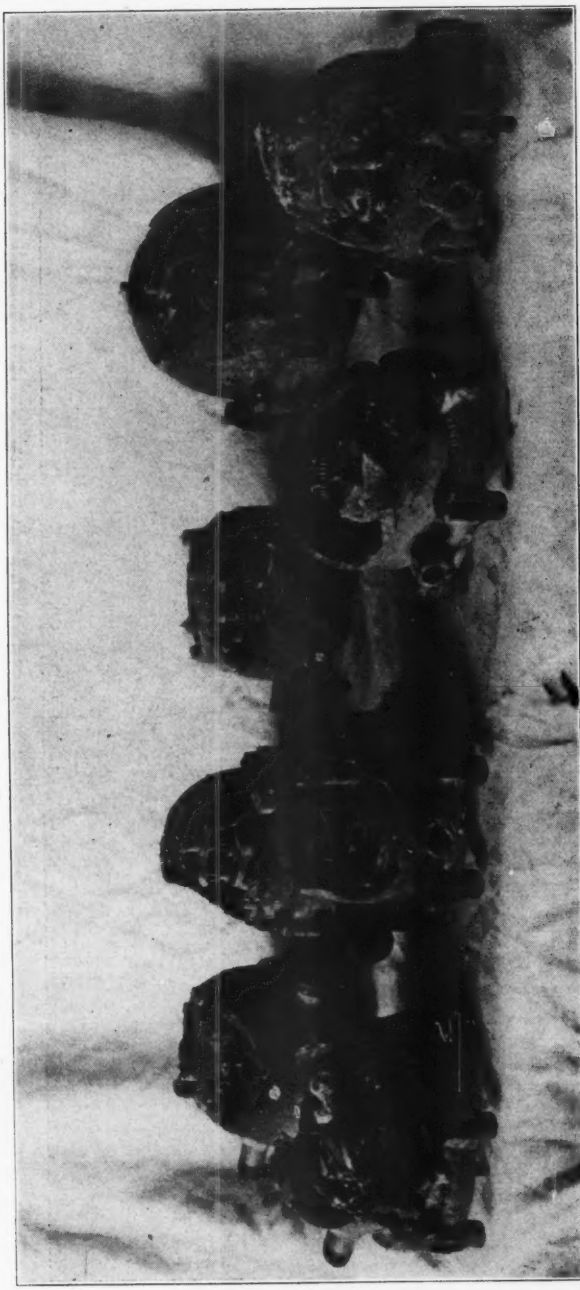


FIG. 3. — NEW WATER METERS DESTROYED BY FIRE.

REVIEW OF NINETEENTH ANNUAL REPORT ON WATER EXAMINATION. LONDON METROPOLITAN WATER BOARD.

REVIEWED BY MELVILLE C. WHIPPLE.*

There is always an element of pleasure, as well as of profit, to be derived from perusal of the reports of Sir Alexander Houston, Director of Water Examination for the Metropolitan Water Board of London. It is, therefore, a pleasant task to prepare this review of the Nineteenth Annual Report, which records some unusually interesting observations upon the subject of chlorination and tastes in drinking water. The report covers the twelvemonth period ending March 31, 1925.

In this country the use of chlorine and its compounds for disinfection of water supplies has too often been attended by the production of obnoxious tastes, either that of excess chlorine, or the so-called iodoform taste which results from combination of chlorine with organic impurities in the water. What is more to be deplored is the lack of sympathy for the protesting consumer sometimes exhibited by water-works officials. It has been a maxim of the London authorities that disinfection must be accomplished without taste production. In the ten years that Thames River water has been treated with chloride of lime, a volume of 76 mil. gal. daily, not a single complaint of taste has been made. Section 1 of the Report deals with the Thames water and shows how consistently the policy of the Board was observed in meeting an unusual situation. As a result of construction operations, incidental to the building of the new Queen Mary Reservoir, Staines aqueduct water became polluted over a considerable period of time with turbid subsoil water. This occurred below the point of chlorination and below the point where residual chlorine is usually found.

The hygienic quality of the water could have been safeguarded by increasing the dose of hypochlorite at Staines, but at the risk of producing tastes which would not be removed by the works below. This was done temporarily, and an elaborate series of examinations for taste and bacteria were begun in order to hold the amount of hypochlorite within bounds. The situation was finally met, however, by constructing, in January, a liquid chlorine plant at Sunbury, below the point of pollution. In addition, two potassium permanganate plants were installed, one at the entrance to the one-day storage basin serving the Sunbury filters, the other near the discharge of the filtered water reservoirs. Permanganate has been found to effectually destroy the iodoform taste. This taste was detected at times in the water going to the filters, but was dispelled from the effluent water

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by use of the second permanganate plant. The first was held in reserve for severe conditions which did not arise.

As a result of the changes outlined above, the bacterial quality of the filtered water was as good as, if not better than, in previous years, and the enviable record of no complaints of taste was maintained. The average dose of chlorine at the new Sunbury installation was 0.32 parts per million and at the Staines plant 0.45. Permanganate costing 14 cents per pound was used on 18 days at the rate of 2 lbs. per mil. gal.

Chlorination of New River Water. Section II deals with the New River, a stream subject to wide fluctuations in quality, the critical periods of the year coming in the winter. The raw water is treated when necessary with liquid chlorine and potassium permanganate. It flows then for a considerable distance to reservoirs and is filtered. The volume chlorinated during the year was 9 418 mil. Imp. gal.; the average dose of chlorine was 0.35 parts per million, and that of permanganate 2.1 lbs. per mil. gal. The following paragraph is evidence of the close control given to treatment:

"It takes about two or three days for flood water to travel from the New River intake down to the reservoirs at Hornsey and Stoke Newington. The method now in vogue is to chlorinate lightly (dose, say, 1 in 4 or 5 millions) in advance of the turbid water reaching Highfield. As the turbidity of the water increases, the dose is raised until it reaches a maximum (say, 1 in 2 millions), and at this stage potassium permanganate (2–8 lbs. per mil. gal.) is added as well to prevent the possibility of taste troubles arising. When the water begins to improve in quality the dose is gradually reduced and the addition of potassium permanganate discontinued, or added in less amount. If no fresh floods occur, the dose of chlorine is allowed slowly to fall to as little as 1 in 5 millions. During the treatment daily tests are made with mixtures of chlorine and New River *raw* water (doses 1 in 0.25, 0.5, 1, 2, 3, 4 and 5 millions) in order to see if any of these mixtures develop a taste. If none develops a taste, or if there is no taste in the mixtures approximating to the current dose at the Works, a feeling of confidence is engendered that taste troubles are unlikely to supervene."

Chlorine and Taste Experiments. Special interest attaches to that part of the Report contained in Section III. Here are recorded experiments by Sir Alexander, by Mr. B. A. Adams, F.C.S., and by Drs. Thresh and Beale. These form one of the most valuable contributions to the subject of chlorine and after-tastes that has come to the writer's attention.

In July and August, 1924, the laboratories of the Water Board carried out a series of taste experiments upon filtered water from the General Well at the Ferry Lane Works. These covered twenty days. On each day portions of water were treated with doses of chlorine, ranging from 0.125 to 8.0 parts per million. After one half hour a portion of the water was dechlorinated with SO_2 solution and tasted. Samples showing taste were then diluted so as to contain from 20 to 80 per cent. of untreated water, and again tasted. Another portion of the chlorinated samples was treated with potassium permanganate, one part in 5 million.

The tabulated results show that the large doses of chlorine, from two to eight parts per million, never produced taste after dechlorination. Likewise, the small doses, 0.25 and 0.125 parts per million, did not cause taste. Nearly all the samples which were dosed with 0.5 and 1.0 part developed an iodoform taste. The indications were that this particular water would be a difficult one to treat, the most economical doses of chlorine and the ones most likely to insure disinfection being the ones to produce fairly consistently an iodoform taste, even after dechlorination with SO_2.

The effect of dilution with untreated water resulted generally in improvement, although the addition with some doses of 80 per cent. untreated to 20 per cent. treated water failed to produce much effect. The stronger tasting samples were less favorably influenced than the weak ones. Taken as a whole the dilution experiments were productive of interest, but did not show that this procedure would destroy a taste already existent. In many cases taste might be masked. The success of the treatment would likely vary with the particular water to be dealt with.

Addition of permanganate after chlorination gave clear-cut results. In only four samples out of 120 was a faint taste detected after addition of 0.2 part per million of potassium permanganate. All the evidence to date from London points to permanganate as a most efficacious substance for the destruction of chlorine after-tastes. It has the disadvantage of increasing slightly the color of the water, and in the absence of organic matter may impart a pink tint.

Chlorine and Phenol Compounds. The experiments of Mr. Adams were first reported in *The Medical Officer*, March 21, 1925, Vol. XXXIII, No. 12. The article is reprinted in full in Sir Alexander Houston's report.

It appears that considerable trouble from the iodoform taste occurred at a plant under Mr. Adams's direction, where well water was softened, chlorinated and allowed to settle in open tanks. The trouble was intermittent in character, being most frequent in October and November and least so in May and June. The affected water sometimes showed an absence of residual chlorine, again a trace.

Investigation proved that the water acquired the taste during times of rainfall, especially if the precipitation followed a long period of good weather. Slow, steady rain, or a warm humid atmosphere, sometimes produced trouble, but the worst conditions were those during a fog, when the water would be "quite unpalatable." The accompanying wind direction was usually, but not always S.W.W., or calm. Other towns lie in every direction, but an industrial city and a large gasworks are located a few miles away to the S.W. Few occurrences of the taste were noted during cold weather, none during fair weather, and only two during daylight.

Taste was never present in water untreated with chlorine compounds, and, what is more remarkable, at no time when the water contained organic coloring matter as a result of surface pollution.

The conclusion reached was that under certain meteorological conditions substances are precipitated from the air into the tanks and that these combine with the added chlorine to form compounds which give distinctive and obnoxious tastes and odors; also, that very small quantities of these impurities are potent. Air contamination was experimentally proved by exposure of chlorinated water having no taste. Two days of fog sufficed to precipitate substances into the exposed water, which gave a strong iodoform taste after addition of 0.2 parts per million of chlorine in the form of sodium hypochlorite. Agitation and exposure to light dissipated the taste. The substances causing it could be collected in the distillate after the sample was boiled.

The natural inference drawn, as a result of common experience with the chlorination of phenol polluted surface waters, was that phenol-like compounds, thrown into the air by distillation and combustion of coal, were capable of precipitation in such amounts as would produce offending tastes after chlorination. Tests upon distilled water through which air had been aspirated gave doubtful phenol reactions, but distinct iodoform tastes when chlorinated; other tests upon rain water gave a phenol indication to the extent of two parts per million (Fox and Gage tar-acid test) and strong tastes. Adams found by experiment that one part of phenol in 1 000 million of well water would produce a noticeable taste with chlorine and even one part in 2 000 million could be detected by sensitive observers. He classes women and children as more sensitive than men to this taste. His calculations show that 0.1 in. of rain having phenol compounds equivalent to one part per million of phenol is sufficient to cause a slight taste in the water at his plant.

Other experiments are cited in contention of the point that phenol derivatives are responsible for the iodoform taste and odor. The latter was produced by carbolic soap when used with water containing excess chlorine and having no taste. Likewise a jug of chlorinated water developed the taste when exposed in a room previously sprayed with a phenol disinfectant.

The summarized results of Adams's work are given as follows:

SUMMARY.

"1. That there is some constituent in the atmosphere at certain times and at certain places, which combines with chlorine added to a water and causes an iodoform taste.

"2. That this constituent is probably of a phenoloid character derived from gasworks and from imperfectly burnt coal.

"3. That the reaction does not take place if the water contains a trace of free ammonia.

"4. Nor does it take place if the chlorinated water is not exposed to air or if the water contains an unusual amount of organic matter.

"5. A chlorinated water should not be exposed to air, at least in the proximity of towns or gasworks, nor afterwards be mixed with water which has been so exposed."

These conclusions have a bearing not only upon the successful treatment of waters which are exposed to atmospheric pollution, but also upon those which contain before treatment phenol derivatives originating in liquid wastes that pollute surface supplies. The latter class of waters presents the greater problem by reason of numerical superiority and the larger volumes treated and consumed. If such waters contain organic nitrogenous substances in amount sufficient to keep the chlorine combined as chloramines, or other compounds, then there should be no free chlorine to combine with phenol compounds and produce an iodoform taste. If the organic content is lacking, addition of ammonia before chlorination should bring about the same result. Such suggested measures for preventive treatment are worthy of consideration in places where after-tastes, not chlorinous in nature, have given trouble.

Work of Thresh and Beale. *The Medical Officer* of May 2, 1925, contained an article by Drs. Thresh and Beale which confirmed and extended the work of Adams. In a series of taste and odor experiments they added various amounts of phenol to deep well water and then 0.25 part per million of chlorine. The results are summarized below:

"1. That the taste is more persistent than the odour.
"2. That there are marked differences between people with reference to taste sensitiveness, and that females appear to be more sensitive than men.
"3. That both males and females could detect the taste when the phenol was 1 in 40 millions.
"4. That the majority (ladies in this case) could detect it in 1 in 2 000 millions.
"5. That some could unhesitatingly detect it in 1 in 5 000 millions.
"6. That when present in 1 in 10 000 millions, no taste could be detected."

Thresh and Beale point to the fact that the intensity of the taste produced does not increase in the same ratio as the concentration of phenol, and that phenol may not in all cases be the cause of the taste. They agree that under proper conditions there may be sufficient phenol, or other compounds, precipitated from the air to produce the effects noted. Their experiments with ammonia as a preventive measure gave conflicting results. Adams is investigating the subject further. Sir Alexander mentions the work of Major Harold (R.A.M.C.), not published at the time of the Report. Harold tentatively claimed for the use of ammonia with chlorine certain advantages: (1) Control of taste, (2) Enhanced sterilizing ability, (3) Possibly reduced costs, (4) Variations in the oxidizability of the water largely eliminated.

Corroborative Experiments of the London Water Laboratories. Following the publication of Adams's work the Metropolitan Water Laboratories conducted a series of 37 experiments dealing with taste production, prevention, and removal. These are given in detail and in summarized form and

confirm previous findings of the Laboratories and, in general, those of Adams.

London air, both unfiltered and filtered through cotton, when passed through tap water, added substances which provoked an iodoform taste with certain doses of chlorine, even after dechlorination with SO_2. The latter does not cause taste in water in moderate excess.

London rain water when mixed with tap water in a proportion as low as one per cent. caused the development of an iodoform taste when 0.5 part per million of chlorine was added.

Tap water containing as low as one part phenol in 1 000 million parts of water took on the taste after addition of 0.5 part per million of chlorine.

Substances found to be effective in combating the taste produced in the presence of phenol bodies were:

1. Organic matter, present in the water to be treated. This may give rise to other tastes than that described as "iodoform."

2. Chlorine. Super-doses followed by dechlorination with SO_2 gave satisfactory results.

3. Potassium permanganate. Addition before or after chlorination was equally effective. From 0.2 to 1.6 parts per million were necessary.

4. Ammonia, ammonium chloride and ammonium sulphate. These must be added in advance of chlorine to be effective.

The chloramines formed appeared ultimately to have a stronger disinfecting action than the same amount of chlorine used alone, although there was a "lagging" effect at first. On the basis of nitrogen content these compounds prevented taste when present in dilutions as high as 0.1 part per million.

The use of ammonia in conjunction with chlorine is by no means new. The work of Rideal and of Race in this connection is well known and will merit renewed interest as a result of these researches. It is obvious that elaboration of the chemical treatment of water will add to the cost of purification, but if the final result is the production of attractive and acceptable water the slight increase in cost becomes almost mandatory. Uncomplaining, satisfied consumers are a greater asset to any water works than a few dollars of surplus obtained at the cost of failure to meet consumers' standards of quality.

All the foregoing experiments are intensely interesting and add to our basic knowledge of certain matters. They are largely, however, on a laboratory scale. It remains to be seen if their application to practice will bear the fruit that is promised. Our English brethren have, so far, blazed the trail for a more scientific control of the disinfection process. It is to be hoped that a broader pathway will develop when use is made of the existing information.

Other Features of the Report. Sections IV to XVII deal with various routine and special subjects of investigation, many of which have been discussed in previous reports.

Section V contains the results of weekly analyses of suspended solids, both volatile and fixed, in the Thames River water. A table of average daily flows arranged by weeks, aids the interpretation of these determinations.

Continuation of the study of prefiltration (stored) waters, both from the bacteriological and chemical viewpoints, is given in Section VI. Chlorination followed by storage effects remarkable improvement in some of the raw waters, particularly in the Bact. coli content. Numerous tables indicate the changes in the bacterial and chemical content and point significantly to the great load removed from the filtration process by the preliminary treatment.

Section VII deals with the Barn Elms experiments. The nine rapid primary filters put in operation there in January, 1923, have worked well. They were designed to remove, without coagulant, algae and suspended particles. The effluent is applied to slow filters. Working at a rate of 125 mil. gal. per acre per day the primary filters have enabled the slow filters to operate at increased rates without loss of purity in the effluent or shortening of runs.

Other sections deal with such subjects as the sterilizing action of permanganate, differentiation tests for Bact. coli, dissolved oxygen in the Thames, and the significance of lactose fermenting, spore-forming organisms.

All the sections contain something of interest, but space will not allow further discussion. The material relating to chlorination and taste prevention should be read by all who are interested in ridding the disinfection process of its stigma of after-tastes.

EFFECT OF DECIDUOUS AND CONIFEROUS FORESTS ON RAINFALL AND RUN-OFF.

[At a recent meeting of the Association the question was raised as to the effect of deciduous and coniferous forests on rainfall and run-off. As a result our President, Mr. Bristol, wrote to several authorities on this subject asking for information. A copy, of one of the replies, follows. — *Editor.*]

New Haven, Conn., Feb. 23, 1926.

Mr. Theodore L. Bristol, President,
New England Water Works Association,
Ansonia, Conn.

Dear Mr. Bristol, — I have your communication of Feb. 20th in reference to the effect of different types of forest on rainfall and on the disposition of the water after it reaches the ground. These are large questions on which there is a mass of literature running back for one or more centuries.

The effect of both hardwood and coniferous forests on rainfall has not been definitely proved. From a purely theoretical consideration forests may influence precipitation slightly, due to the effect which the forest has on air, temperature, and relative humidity. This effect of the forest is local.

Many efforts have been made during the past century to study rainfall on denuded areas and rainfall on forested areas, otherwise comparable with the former, and compare the results. These studies have been made by means both of radial and double stations. The results obtained by some of the investigators appear to show *that the forest increases rainfall, often as much as 40 or more per cent.* The results obtained by other investigators, following the same methods at other times and at other places, appear to indicate that the forest *does not increase precipitation.* In fact, some of these data appear to show that the forest *actually causes a marked decrease in precipitation.* When we sum up all the data that have been obtained by instrumentation at both double and radial stations, we find it so contradictory, one cannot say that there is acceptable proof that the forest increases local precipitation to a measurable degree. Personally, I believe it doubtful that the presence or absence of a forest in a particular place influences appreciably the amount of precipitation in that place. The precipitation in a given place depends on dynamic forces beyond the control of vegetation.

Zon and some others contend that the forest has greater influence on general precipitation than on local precipitation. This is explained as

follows. For instance, moisture-laden winds from the Gulf of Mexico moving northwest precipitate their moisture in the coast forests. These forests, however, due to their large transpiration, return their moisture to the air which, moving further inland, again precipitates it in other forests. These forests in turn by their transpiration return the water to the air and is again carried further inland. This operation is repeated again and again in forested regions.

It is contended if the forest is cut away along the coast or further inland, not nearly so much of the precipitation is returned to the air to be later precipitated further inland. Thus the large stretches of southern forests in Mississippi, Louisiana, and Arkansas keep eastern Nebraska and Kansas from becoming too dry for agricultural purposes. In my judgment this is pure speculation which does not permit of proof.

Although the effect of the forest on precipitation has not been proved, and it is doubtful if there is any appreciable effect, the forest does decidedly affect the disposition of the water after it reaches the ground. This permits of definite proof. When precipitation falls on the ground it runs over the surface into the drainage, returns to the air through evaporation and transpiration, or it sinks into the ground. *The forest has a far-reaching effect in determining the amount of the precipitation that sinks into the ground to later feed the streams and support the vegetation.* It can be readily seen that if a watershed is absolutely bare and the soil compact, it acts a good deal the same as the roof of a house, that is, the larger part of the precipitation flows over the surface and the streams quickly reach flood height. Only the minimum of the precipitation gets into the soil and thus becomes of constructive value. On the whole, we can say, therefore, that *the forest permits much more of the precipitation to sink into the soil than in the case of bare land.* In fact, under the most favorable conditions of forest cover practically all of the precipitation which reaches the ground sinks into the soil, while under the most unfavorable conditions in the open almost all of the precipitation passes over the surface. Of course there is every gradation between these two extremes, depending very largely on the character of the vegetation, the topography and the surface conditions. The favorableness of the latter depends almost entirely on the forest.

Now the water that sinks into the soil, for the most part, escapes again from the soil by seeping through it to lower elevations where it feeds the streams and keeps them alive for more or less extended periods after precipitation stops, or it is taken up by the roots of plants and enters the transpiration current and escapes into the air through the leaves. Some is also lost by evaporation from the surface. The amount that is taken up by the vegetation depends upon what the vegetation is. Forests, on the whole, consume during the growing season a very large percentage of the water which passes into the soil at times of precipitation, often 50 per cent. or even more. The forests, therefore, *not only cause a large part of the precipitation to enter the soil but they also consume a large part of that which enters.*

Under average conditions it is safe to say that a fully denuded watershed with compact soil will bring a much larger volume to the reservoir of a given drainage area in the course of a year than would enter it if the same drainage area was fully stocked with mature timber. In other words, the denuded area acts like the roof of a house where practically all the precipitation enters the cistern. In this case, however, the water is nearly all flood-water which carries with it sediment and other matter resting on the surface, and there is little water entering the reservoir through seepage into the soil and later appearing in the drainage. In the case of the fully stocked stand of timber, *although the volume of the water crop is less,* most of the water which entered the reservoir is seepage water and little of it enters the streams which feed the reservoir by flowing over the surface.

From the standpoint of the potable water crop, it is desirable, first, that the flood height of the reservoir and the streams which feed it be reduced, as this excess water is useless and of destructive significance; second, that the water yield of the drainage area be maintained at as high a level as possible during periods *when precipitation is absent or scanty.* This is the water of constructive significance. It is that part of the precipitation which enters the soil and gradually seeps into the streams feeding the reservoir; and third, that the yield of the drainage area be free from pollution and other matter in suspension. This requires that the water crop reach the streams and reservoir, so far as possible, as seepage water rather than as surface flow.

Forest cover is *the only practical means for favorably influencing each of the above.* (1) It reduces flood height in streams and reservoirs to a greater or less extent; (2) By increasing the amount of precipitation that sinks into the soil it tends to increase stream flow for more or less extended periods after precipitation ceases; (3) It reduces or entirely stops the flow of water over the surface before it reaches the streams and thus renders it free of sediment and, by its seepage through the soil, prevents pollution.

Balanced against these favorable influences of the forest as important factors in drainage area management for potable water, and even for water yield for other purposes, must be considered the effect of the forest in *consuming the precipitation that sinks into the soil and thus inhibiting its reaching the reservoir as seepage water.*

It is clear that the more that the vegetation consumes and returns to the air through the transpiration current, the less there will be to slowly seep into the streams during periods of drought and sustain the volume of water in the reservoir. As much as possible of this seepage water should enter the streams and feed the reservoirs; as little as possible should be returned to the air in the transpiration current. It is here that the difference between the effect of the hardwood forests and the coniferous forest is most marked. The coniferous forest returns to the air, through the transpiration current, only from 10 to 20 per cent. as much water as a broadleaf forest like beech or maple, that has large, flat leaves. For this reason a

coniferous forest is more desirable than a broad-leaved forest for watershed protection.

During recent years I have made a study of the moisture in the soil at intervals during the growing season, both in the mature forest and on open areas devoid of all vegetation. Due to the enormous demand of the mature forest for water to supply the transpiration current, I find that the forest soil becomes progressively drier, on the whole, from spring to autumn, and during the late summer and autumn is very much drier than similar soil in the open where there is no vegetation at all. *Contrary to the generally expressed opinion, forest soil is much drier during the summer and autumn than is similar soil without vegetation.*

As a summary, the drainage area which feeds a reservoir should be kept in forest, preferably coniferous, *not for the purpose of increasing the total water crop* from the drainage area, but, first, for the purpose of distributing the water crop over a longer period following precipitation; and, second, for the purpose of permitting the larger part of the precipitation to be taken up by the soil and the smaller part to flow immediately over the surface, thus decreasing the pollution and sediment which reaches the reservoir. It is water which sinks into the soil and which later seeps into the streams and reaches the reservoir that is of great constructive significance. It is the water that passes over the surface to the streams that is flood water, and usually of destructive significance.

Most sincerely yours,

J. W. TOUMEY,

Professor of Silviculture,
Yale School of Forestry.

THE MASSACHUSETTS WATER REPORT.

BY ALLEN HAZEN.*

[*Read March 9, 1926.*]

[Since this paper was presented by Mr. Hazen and discussed by Colonel Gow, many requests have been made that the report of the Metropolitan Supply Investigating Commission be printed in the JOURNAL. Accordingly this report is printed on page 61. This does not include the engineers' reports, which may be found in House Document No. 900. — EDITOR.]

Thirty years ago, the Metropolian Water Board was formed to take over some of the existing sources of supply, to develop them and to add new ones, especially the South Branch of the Nashua River, which has since been called the Wachusett system, and to supply water at wholesale to those communities that elected to join the district. During the thirty years of its operation an ample supply of good water has been maintained in the district. The primary object of furnishing an acceptable water supply has thus been achieved during this period.

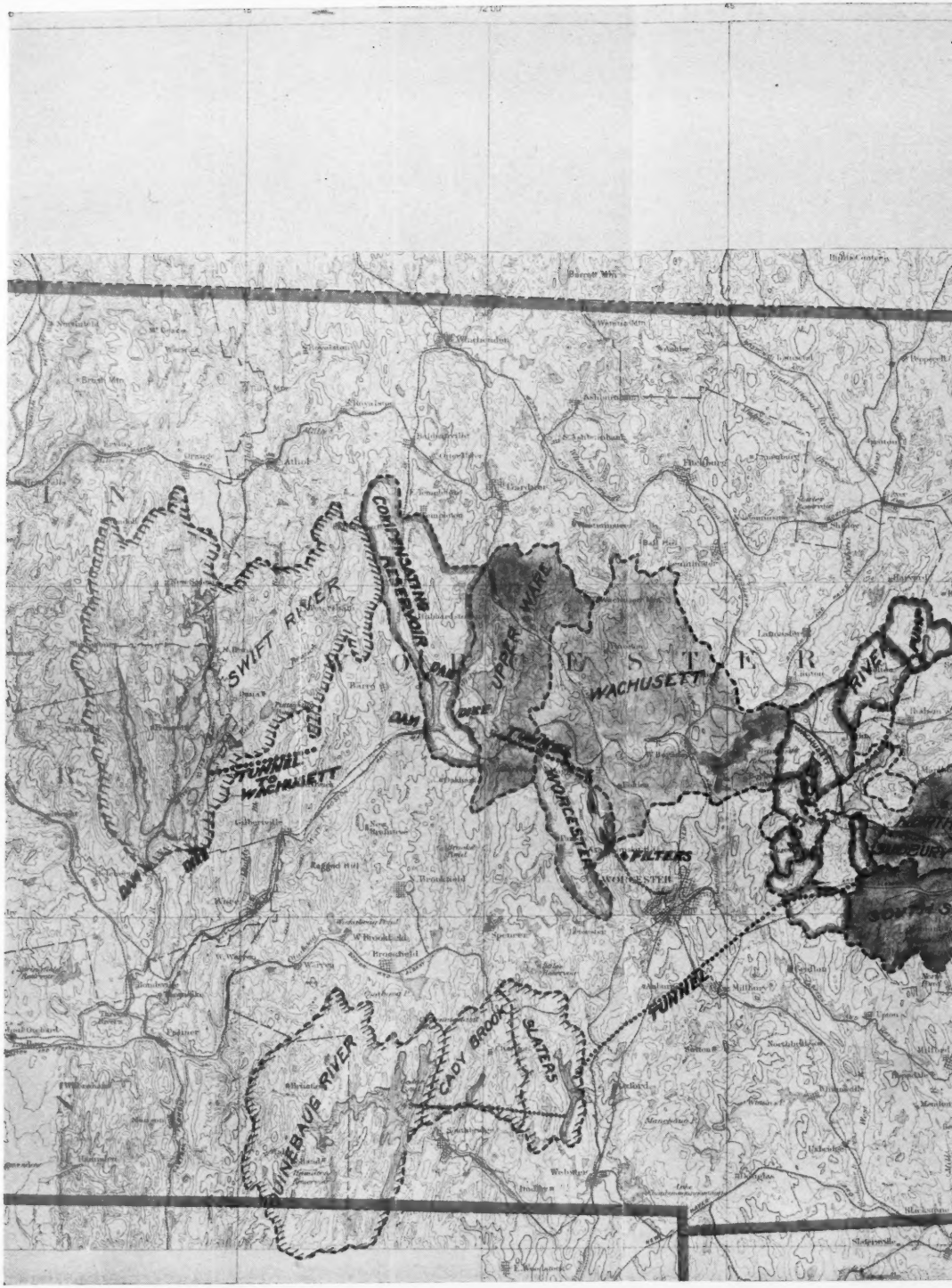
The business has been profitable, and it has been profitable both to the individual cities and to the district. At moderate water rates, only a very little higher than those of thirty years ago, the individual cities have paid their operating expenses; have extended their works; and have paid off almost all of their indebtedness. They now enjoy surplus earnings above direct requirements considerably in excess of one million dollars per year. These are net profits from the retail sale of water to takers.

To the district also the business has been profitable. It has accumulated a surplus of something like $25 000 000, an average of about $800 000 per year. This surplus is more than is really necessary for sound financing, but it must be stated that it has resulted, not from the judgment or discretion of the Metropolitan Water Board or its successors, but from the legal requirements of the laws of the Commonwealth. These laws required, in the first place, that sinking funds should be set aside to retire the indebtedness in a limited number of years. In recent years serial bonds have been substituted for sinking funds.

The water-works lands, rights and structures acquired and owned by the district, are permanent in character. Many of the largest items suffer no depreciation, and the allowances required by law have been greatly in excess of the actual depreciation of the plant. That is why the surplus has been accumulated. By surplus, I mean that the plant as it stands today is worth $25 000 000 more than its remaining outstanding indebtedness.

Taking the business as a whole, including the operations of both the Metropolitan Water District and the various communities composing it,

* Of Hazen & Whipple, Civil Engineers, New York City.



MAP SHOWING LOCATION O

ON OF PROPOSED SOURCES OF SUPPLY.

the works show a net income above all requirements of more than $2 000 000 per year at the present time. No money has ever been raised by taxes to support the works.

At this time it may be well to remember that F. P. Stearns was the engineer who made the report of 1895, on which this wonderful development was based. Hiram F. Mills, chairman of the committee in charge, selected Mr. Stearns for the position, and actively followed the work throughout. Dr. Henry P. Walcott was chairman of the State Board of Health, that did the preliminary work, and of the Metropolitan Water Board that carried out the recommendations and built the works. To these men primarily belongs the credit for this magnificent piece of work. Credit must also be given to Desmond FitzGerald, then engineer of the Boston City Water Works, to Dexter Brackett, and to the consulting engineer, Joseph P. Davis, and also to Alphonse Fteley, who had in their turn been engineers of the city of Boston or its water department.

In these thirty years since 1895, the water business has doubled; the population has increased 78 per cent.; the valuation 118 per cent.; the water consumption 86 per cent., and the water revenue 118 per cent.

The present consumption is still considerably under the limit of capacity of the combined works set out by Stearns in 1895, but this apparent reserve cannot now be availed of. There are several reasons for this. There has been a very considerable increase in population, and even of industries upon several of the catchment areas supplying water, resulting in increased pollution of the water. At the same time standards of quality have advanced tremendously. Water considered satisfactory in 1895 may be far below the reasonable requirements of 1926.

On Lake Cochituate, the rapidly growing towns of Framingham and Natick, with other communities, have brought the population to 1 200 per sq. mile, and are growing fast. We think the time has come when Lake Cochituate should be marked off as part of the regular supply. It may still be retained for a time as a reserve, for use in special conditions and with due precautions. *This is not saying that it would not be possible to filter* this water and obtain a fairly good supply from it, but it is not pleasant and it is not necessary to take our public water supplies from such densely populated areas. On the Sudbury catchment area the present population is between 300 and 400 per sq. mile, and is increasing. Perhaps in another generation Sudbury will follow Cochituate into the reserve, but at present this water can be filtered and restored to use. At present much of it is not used, and is not of a quality that will permit it to be used in its raw state.

Another matter that affects the capacity of the present sources is the purification of water by storage. The dry year capacities were estimated by Stearns in 1895 upon the basis that all stored water would be used when needed to maintain service. But the quality of Wachusett water is dependent upon long storage in the Wachusett reservoir. To maintain this quality the reservoir must be maintained more or less full. If it and the

other reservoirs are drawn down to maintain quantity there will be deterioration in quality, because the storage is cut off, and water that has not benefited by it will form a large part in the mix in the reservoir at times. Under present conditions an important part of the total storage must be dedicated to maintaining quality, and when this is done the quantity that may be drawn is considerably reduced.

In addition to all these matters Worcester has taken about eight square miles of the Wachusett area, as she was authorized to do, and in addition has been recently supplied with further quantities of water pumped from the Wachusett reservoir.

Under all these conditions more water is now being supplied from the Metropolitan Water Works system than the available supply of fairly good water in a dry time. Works for securing an additional supply should have been started some years ago to meet standards of ordinary business prudence.

I have spoken so far of the sources of supply. The delivery of water from those sources to the takers is equally important and needs attention equally at the present time.

When the Metropolitan Water Works were first built, all the water was brought through the previously built Cochituate and Sudbury aqueducts. These had been built anticipating growth, and had the necessary reserve capacity. After some years these became inadequate and the Weston Aqueduct was built, with a carrying capacity for the then present needs and liberally anticipating future growth. It went only to a terminal in the town of Weston. Since then a very small part of the Weston Aqueduct capacity has been availed of by pipe connections leading into the district. The old Sudbury aqueduct is still the main reliance. These aqueducts and pipes at the present time are sufficient to bring in the quantity of water needed for daily use, with a very small margin. Common prudence requires that there should be an ample margin to meet such unusual conditions as are known by experience to recur from time to time, and also to permit various structures to be put out of service temporarily, for inspection and repair. Present conditions in this respect are altogether too close for comfort, and will steadily grow worse as the output increases.

The time has come to extend the Weston Aqueduct as a pressure tunnel, through the heart of the Metropolitan district, giving ample connections with all main parts of the present pipe systems. According to Crosby's geological maps, such a pressure tunnel, several hundred feet below tide, would be in hard shale rock for its entire distance. This, of course, must be tested and proved by borings before the tunnel is finally located.

The route tentatively selected by Leonard Metcalf, who acted as consulting engineer in the late investigation, would go as a straight line from the present terminal to a point near the eastern end of Corey Hill; thence under Beacon Street to the Back Bay Fens, and under the Charles River basin to a point south of the easterly end of the Charles River Dam; thence

under the channel to a point near Bunker Hill Monument; thence under the Mystic River to a point in Everett, where connection would be made with the northern distribution system.

Bringing large additional quantities of water to and through the district by pipes laid in city streets will be too difficult and expensive for the next generation, and the deep pressure tunnel, with connections to the surface pipes at intervals along its length, is clearly the best means of securing the needed capacity. And this addition to delivering capacity is as important and as urgent to the district at this time as additional sources of supply.

In 1895, Mr. Stearns, after outlining the present system of supply, proposed in general terms future extensions beginning with the Assabet, followed by the Ware, and later by the Swift rivers. A few years ago when it became necessary to consider additional water supply, a Joint Board created by the Legislature, consisting of the State Department of Health and the Metropolitan Commission, with X. H. Goodnough as engineer and J. Waldo Smith as consulting engineer, prepared a program of development following Mr. Stearns's outline, but differing from it in numerous particulars. These variations were natural and grew out of changed conditions and changes in the art, and do not require discussion at this time. There was opposition to this program, and, as you know, it was not authorized.

The recent Board, a Special Commission, consisting of Col. Charles R. Gow of Boston, George F. Booth of Worcester, and E. E. Lochridge of Springfield, for whom the writer had the privilege of serving as engineer, was directed to consider, among other things, other feasible sources of water supply, including water purified by filtration, etc.

In taking this matter up during the last years under these instructions, not only what we may call the western projects were considered, but also a study was made of all promising sources of supply in the eastern part of the State, where water of satisfactory quality could be obtained by the aid of filtration.

In making these studies we started with the ideas, first, that if any existing water supplies were hit in any way, they must be absolutely protected; second, that water needed for process water in mills, or for maintaining sanitary conditions in streams, must be maintained. Where water was proposed to be taken from any stream, with reference to these conditions, enough water must be allowed to remain or to be returned from compensating reservoirs to fully maintain present conditions. This has, I believe, been rigorously carried out in each of the projects considered. Third, where water power was affected, compensation in cash could be assumed, and this would frequently be the only compensation that could be provided. In other words, water power was to be taken and paid for if needed, but process water and municipal supplies must be protected.

As a result of study of numerous projects, a number were selected for presentation in the report. These included the Ipswich River, where it is

possible to obtain a supply of 80 mil. gal. per day from an area of 118 sq. miles, by the construction of a very large reservoir, flooding land that, for the most part, is unused and has very moderate value at the present time. Several local communities take their water supplies from the Ipswich River, or its tributaries, at the present time. These rights would not be taken or impaired in any way, but whatever water was taken under these rights or the extension and development of them, would be deducted from the 80 mil. gal. gross yield. Assuming probable requirements of these local communities, in the time to be reasonably considered, at 30 m.g.d., this would leave 50 m.g.d. for use in the Metropolitan District. The only industry affected by this taking is one mill on the Ipswich River, using a few feet head for power, and also requiring process water. The power would be taken and paid for, but a reasonable flow for process water must be maintained. The study was not carried to the point of determining exactly what the allowance for process water should be; but a considerable area above the mills and below the proposed reservoir would aid in furnishing this process water, and would reduce largely the amount necessary to be drawn from the reservoir to maintain it.

Another development, centering upon the present water-works system, is the Assabet area with an addition of 60 sq. miles. The Assabet area rides as a saddle over the Wachusett aqueduct, and can be diverted to it. That is what primarily makes it economical and financially attractive. Flood flows mainly would be taken, and there is little opportunity for storage. To avoid existing sources of pollution in the lower valleys, tributaries would be taken at numerous places, collected by a system of conduits that flow, with pumping where necessary, to the aqueduct. By the use of flood flows from the Assabet tributaries, delivered to the aqueduct which comes from the Wachusett reservoir, these waters would be used when available; and the Wachusett reservoir would fill faster, stay full longer, and empty less rapidly than it now does, and the capacity of the system would be correspondingly increased. The present Sudbury Reservoir would act as the balance wheel for this system.

The Assabet water requires filtration, and mixing it with Wachusett water compels filtration of the whole supply. It is therefore proposed to filter all the present water, including that from the Sudbury system not now available because of quality. In this way 42 m.g.d. of water of poor quality in the present works will be reclaimed and made available, and 47 m.g.d. additional will be added by the Assabet development. The capacity of the whole combined system, excluding Cochituate, will then be 208 m.g.d.

The Assabet taking would cut the process water and power for important mills below. The power cannot be fully protected. This must be taken and paid for. But the process water can and must be protected. A reservoir, holding between two and three billion gallons, above Hudson, filled by spring floods, and drawn as needed, will more than maintain present low water flows, and furnish all needed process water. Sanitary conditions

and boating on the Concord River will be fully maintained and even slightly improved.

One of the duties of the commission was to provide a plan for an adequate supply for Worcester. The plan proposed is to supply Worcester from a large reservoir to be constructed on the upper Ware River at Barre Falls, where its catchment area is 57 sq. miles.

The water from this reservoir will be taken through a tunnel five miles long into one of the upper reservoirs of the present Worcester system, passing on its way through the headwaters of the Wachusett reservoir at a point where water can be drawn to the Wachusett system as desired. Worcester is high in elevation and this upper Ware source is the only one high enough to give Worcester a full gravity supply. One other proposed supply, Stiles Pond, would give a relatively small quantity of gravity water, but otherwise pumping would be required.

There seemed to be no question but that this upper Ware supply is the best for Worcester. The quantity available, 45 m.g.d., is much greater than Worcester will need for the present or for a long term of years. It is proposed to develop the North Ware for Worcester, but, for the present, as a partnership account by which the Metropolitan Water District will pay the greater part of the construction cost, will operate the works as long as it takes most of the water, but turning the reservoir over to Worcester in installments from time to time, as water is needed. Worcester on her part would be required to pay for the installments of capacity at cost, from time to time, until in the end she would have paid back the entire construction cost of the system. The Metropolitan District would have advanced some of the money and would have had some of the water from it during the interval.

The chief objection to this upper Ware supply is the great use of water for industrial purposes, both for process water and for power on the Ware River and the Chicopee River, into which it flows. To permit the use of this water by Worcester and by the Metropolitan District, and at the same time to prevent or minimize damages to the industries down the river, it is proposed to build a compensating reservoir at Coldbrook, controlling the next 43 sq. miles of Ware catchment area below the proposed point of intake. We calculated that a reservoir holding eight billion gallons at this point, drawn as needed to maintain process water and power, would leave as much available power in the river as can be now used. For good measure this was increased to eleven billion gallons, which is probably large enough to balance and utilize practically the entire flows of the area to be controlled by it.

With this reservoir built the flows would no doubt be controlled by a committee of the industries that use the water, and the method of drawing would be determined by them. Without attempting to forecast what they would do, it is my thought that a scheme of drawing would be arranged, such that the reservoir would not become entirely emptied ordinarily, but

that sufficient reserve would be maintained to insure a supply of process water well up to or somewhat above the present standards at all times; and that the capacity of the reservoir beyond the reserve necessary to maintain this process water would be drawn for power as fast and as rapidly as the mill owners desired.

It is understood that the State or Metropolitan District cannot require mill owners to accept this water in lieu of money damages. Under the Constitution of the United States and decisions of the courts, the riparian owners would be entitled to money damages if they demanded them. The question of preference was submitted to the mill owners, and an expression was obtained from them that they preferred water to money, and would prefer the compensating reservoir to cash damages. Studies were therefore made for a compensating reservoir, and the bill proposed by the Commission to the Legislature provides that the District is authorized to make contracts with riparian owners, and provides that the compensating reservoir shall not be built unless contracts in suitable form with owners have been made, representing 90 per cent. of the total amount otherwise due as damages.

This provision may have led to some misunderstandings, but I think you will see that something like it is absolutely necessary. If the bill provided definitely for the construction of the reservoir and stopped, the reservoir would be built, water compensation would be furnished, and every owner could sue for and recover full damages as if the reservoir had not been built. In other words, compensation would be given twice throughout. The only legal way of proceeding with this idea, is by getting voluntary contracts with the riparian owners, and the only way that these contracts can be negotiated is to leave the business at the discretion of the commission to negotiate and arrange as advantageously as it can. We feel that everything has been done that possibly could be done to protect the interests of riparian owners and at the same time to safeguard the interests of the district and Worcester in the water supply to be obtained.

I may add that the business at Hartford, Conn., was worked out in a similar way, to the advantage, I believe, of both the city and the manufacturers; although of course everyone is not satisfied in any event.

Without attempting to follow these matters further, it is apparent that there are two general ways of getting additional water for the Metropolitan District. First, to develop the great Swift reservoir, with or without some of the neighboring streams, securing in this way a water of the greatest natural purity which can be used without filtration. It may be said that filtration would improve it, but it would probably be fully equal in quality to the present Wachusett water without this treatment.

The other and alternate way suggested and required to be investigated by the Act creating the recent Commission, and largely followed by us in our recent works, is to secure a water supply by filtering, first, the unused waters of the present system; and second, by adding waters from the Ware, Assabet and Ipswich rivers with filtration.

There are numerous possible alternate arrangements in the program at either end, and precise comparisons are difficult, but in a general way enough water to double present business and requirements can be obtained in either of these two ways. In either case the water will be of good quality, and it may be that the filtered Ipswich and Assabet waters will more than equal the Swift water without filtration. At any rate either procedure would be satisfactory from this standpoint.

In the matter of cost, the details of which I am not going to attempt to explain to you today, there is no very radical difference. To secure a given quantity of water by filtering present sources, and by adding new ones to them in the east, will cost about as much as to secure an equivalent quantity without filtration from the Swift and neighboring streams in the west. But in one respect there is an important difference. The Swift system, or the major part of it, would have to be built at first, and before any water was available from it. It cannot now be built quickly enough to prevent an early shortage of water, and some part of the other project would have to be built as an auxiliary to the Swift if it were adopted at this time. A supply from the eastern sources, on the other hand, can be added in installments from time to time; and while the total capital cost may ultimately be as great, the carrying charges through a long term of years will be materially less. The eastern supplies would therefore be easier to finance and would require a less considerable increase in water rates.

I am coming now to another phase of the whole water supply problem of the future that interests me very deeply. That is how far these potential sources are now available and will remain available for use when wanted. What steps can be taken now and in the near future to guarantee that these potential sources are permanently retained and held available for use until they are wanted? This is perhaps the most important problem of all. This question is not peculiar to Massachusetts. It is coming up as a tremendously important matter in many States.

In 1895, when Mr. Stearns made his report, rural land values had been declining for years and were very low. The great modern development of power by hydro-electric plants had not begun, or at least had not gone far enough so that its future importance was realized. If it had been then desired I have no doubt that the necessary property and rights for the control of every one of the sources of supply now under consideration could have been secured on terms that today would look extremely advantageous. It would have been a wonderful thing for the Commonwealth if these sources could have been secured and reserved; but who could then have foreseen, in 1895, the development that has since taken place? There is first the automobile and the building of state roads through all the back country, increasing its availability for agricultural operations, and for summer and permanent residents. There is the development of manufacturing with the addition of electricity and all the improvements that have been made in generating and transmitting power. The interest in these

back lands and in the water power and process water that is capable of being produced by them is enormously greater than it was thirty years ago.

The hearings by the committee of the Legislature in the last weeks have made it apparent that there is the strongest kind of opposition to development of any of the proposed sources; and this notwithstanding the fact that every possible effort has been made in the plans to protect local interests and reduce to an absolute minimum unavoidable injury to private property and to industries. And if this opposition is so great in 1926, what will it be in another generation for the takings that may then be necessary?

With filtration it is possible to successfully produce good water from areas carrying considerable populations; but there is a limit to this, and in any case population upon catchment areas used for public water supply is undesirable and should be kept at a minimum. In the present works of the Metropolitan District, it would have been fortunate if much more land for protective purposes had been secured. In the works now proposed it is not our thought that it will be necessary to remove present population well above the flow-line, where the people are disposed to stay and live under reasonable rules and regulations to protect the quality of the water. But it certainly is desirable that on all present and proposed areas some steps be taken to prevent the establishment of new centers of population and of new industries such as are to be found in numerous instances upon existing catchment areas.

What we need for the State is something corresponding to the zoning of cities. That is to say, setting aside areas for future water supply and preventing industrial and suburban developments upon them, not with the idea of reducing future population and industry in the Commonwealth, but of requiring it to go to areas which are not restricted in this respect. There is plenty of land in the Commonwealth for all the development in sight, and this is equally true if all land needed for future water supply is taken for such development.

At present the only certain legal method of securing this result, is by the immediate purchase of such lands and rights as are necessary to reasonably control areas for future development.

In the present report it is recommended that these areas for future development be purchased to an extent that will permit the water business to be again doubled.

Whether doubling the water business again will provide for a growth of a thirty-year period as in the past, or for a forty-year period, or for a much longer period with slower growth, is something that we cannot determine; but with reference to present conditions and present tendencies, it seems that such control of potential resources to this extent is the least that this generation can do to safeguard the interests of those that are to come.

DISCUSSION.

COLONEL CHARLES R. GOW.* Mr. Chairman and fellow members: I think it may be said that, had the special commission foreseen the extent and character of the discussion which was to follow, they might conceivably have submitted a somewhat more militant report. The present situation reminds me very much of the old story concerning the Irishman who entered a barroom while a fist fight was in progress and who inquired if it was a private fight or one that anybody could get into. (*Laughter.*) So far there has been no limitation placed upon participation in this particular quarrel.

I think at the outset I should like to concentrate your attention upon the thought that there is nothing particularly radical or original in what our commission has recommended. As a matter of fact, the so-called Joint Commission report and the special commission report follow in general, with some modification of detail, recommendations made by the original commission of 1895. In other words, the Assabet, Ware, and Swift rivers were suggested as prospective sources of future supply by the earlier board, and they likewise form the basis of present recommendations in one form or another by the two more recent commissions.

The proposal to utilize the Ipswich River as a final step in our suggested program, is the only material deviation from the original recommendations, and even this feature is not new. Its use as a water supply was considered by the 1895 commission and it has since been recognized as the sole dependence of the several cities and towns of Essex County for supplying their future water requirements unless they are to become participants in the metropolitan water system.

Seven such local communities now secure their supplies in whole or in part from the watershed of this river and they will, before many years, require some such development as that recommended in our report in order to obtain necessary additions to their requirements. The cost of such a development will probably be financially prohibitive, from their standpoint, and the quantity of water made available will be greatly in excess of their own needs.

It was our thought therefore that under these conditions this potential supply should be considered as a possible feature in the future development of the metropolitan supply, since its inclusion in a future comprehensive plan, such as that under discussion, would serve the double purpose of aiding the solution of not only the remote problems of the present metropolitan district but also those of the local communities referred to. In any event it would serve to prevent at some future time the probable inclusion in the metropolitan system of these Essex County communities, with the resulting burden of securing additional amounts of water from distant sources in order to care for their needs.

If this one recommendation be excepted, it may be said that the three

* Chairman, Metropolitan Water Supply Investigating Commission.

commissions that have considered the subject of a future water supply for the metropolitan district have been in substantial agreement as to the probable sources from which that supply was ultimately to come.

The original Metropolitan Commission of 1895 suggested as the next step following the Wachusett supply, the development of the Assabet River by diverting the waters of certain tributaries of that stream into the Wachusett Aqueduct which passes through the Assabet watershed at a level which it was estimated would permit the collection by gravity of approximately 28 million gal. per day from this source.

Following this development it was proposed to go to the Ware River on which a reservoir would be created by constructing a dam across the valley at a point just below the village of Coldbrook and intercepting the flow from approximately 100 sq. miles of watershed. This supply was estimated to yield some 71 million gal. per day.

By building a conduit from the Wachusett reservoir to this proposed Ware River development, of sufficient size and at a low elevation, it would be possible at a later time to continue it to the Swift River valley where another supply could be made available by the construction of a great reservoir capable of yielding 129 million gal. per day of additional water; and it was also suggested, as a remote future possibility, that these supplies could be further augmented by extensions to even more distant sources.

The Joint Commission, so called, recommended in its 1922 report a program for development which closely followed the suggestions of the earlier board. It is true that this second commission eliminated the Assabet supply from consideration largely because of its belief that any substantial diversion of water from the upper tributaries would create objectionable dry-weather conditions in the river below the proposed points of taking, both as regards manufacturing and sanitary requirements.

Otherwise the Joint Commission report followed the earlier recommendations, with some modification in detail. It proposed the successive taking of Ware and Swift rivers at practically the same points previously suggested for that purpose. Instead of taking the entire flow, however, the Joint Commission proposed to divert only the flood flows above 1.2 second ft. per sq. mile of watershed, thus maintaining a sufficient flow in the streams below the points of taking to supply normal power requirements and process water for the industries now dependent upon the present stream flow.

Accordingly, it was not deemed necessary to construct the reservoir originally contemplated on the Ware River, but a simple diversion intake was proposed which would permit the excess flow to spill into a vertical shaft and thus be delivered into the low-level tunnel. By this means it was expected to secure a supply from the Ware River averaging 33 million gal. per day until such time as the Swift River reservoir should be built, after which the yield from the Ware diversion could be increased to 47 million gal. per day. The increased yield of 14 million gal. per day, when

used in conjunction with the Swift supply, would be made possible because of the ability to divert water in both directions from the Ware intake shaft at Coldbrook. These two figures of 33 and 47 million gal. per day, respectively, from the Ware River, compare with the 71 million gal. per day proposed to be taken by the earlier board, utilizing the entire stream flow.

The Joint Commission proposed also to build the reservoir in the Swift River valley in substantial accordance with the earlier recommendation. This reservoir would contain approximately 400 billion gal. of storage. As in the case of the Ware River, the Joint Commission recommended the taking of flood flows only above 1.2 second ft. per sq. mile, and in order to secure the same aggregate supply as provided by the earlier report it contemplated the diversion of the flood flows of the Millers River into the Swift reservoir so that the total supply secured from the three sources, Ware, Swift and Millers rivers, using flood flows only, would equal the amount estimated by the earlier board to be obtained from the Ware and Swift rivers alone, utilizing their entire stream flows.

The more recent special commission, of which I was a member, in reviewing the recommendations of the two previous boards reached the conclusion that the Assabet supply was too valuable and too accessible to warrant ignoring it entirely. We found that the 28 million gal. per day of gravity supply, referred to by the 1895 commission, could be developed much more cheaply than any other supply and that in addition approximately 20 million gal. per day of additional supply could be secured by low-lift pumping, utilizing other tributaries. In order to meet the objections of the second commission as to dry-weather flow conditions in the lower stretches of the river, it was found it would be possible to build a compensating reservoir on the river a short distance above the town of Hudson, which would retain a sufficient volume of the flood flows of wet seasons with which to maintain the river at a considerably higher rate of flow during the dry season than obtains under natural conditions.

Because of the relatively high color of this water, however, and since it would have to be taken intermittently in comparatively large doses, mixing immediately with the Sudbury reservoir water, which is itself of doubtful quality, it was our conviction that the introduction of the Assabet supply at this time would necessarily involve the filtration of the entire supply.

There is serious question whether the time has not already arrived for adopting complete filtration of the present supply. Mr. Hazen believes that it has. The Joint Commission and their engineers stated in their report that such filtration was inevitable in the not distant future. We believe it could be deferred for perhaps another ten years but not after the Assabet supply was introduced. For this reason, and another that I shall mention presently, we decided to adopt the Assabet supply as a second rather than first step in our suggested program.

In addition to finding a new supply for the metropolitan district our

commission was charged with the duty of recommending an additional source of supply for the city of Worcester, that municipality having reached the limit of capacity of its existing supplies. The suggested development of the Assabet River would not be of any assistance in solving Worcester's problem. The latter city is located at a very high elevation and there are therefore few sources available which would furnish the city with a gravity supply. In the plan recommended by the Joint Commission it was proposed that Worcester should pump water from the low-level tunnel from the Ware River, elevating it some 500 ft., to one of its reservoirs. The practical difficulties and expense of this method of supplying Worcester with its entire future water supply imposed what seemed to us an unjust burden upon that city. We were in agreement with the two previous boards that the Ware River was the logical source from which to secure an additional supply after the Assabet development had been temporarily deferred, and it was to that source that we looked for a supply which would care jointly for the immediate needs of both Worcester and the metropolitan district.

We found that there was a splendid reservoir site just above the village of Barre Falls, with a watershed of about 57 sq. miles located at an elevation which would permit a gravity flow through a single conduit which could be made to deliver either to one of the existing Worcester reservoirs or to Wachusett. This supply was estimated to yield from 45 to 50 million gal. per day, or considerably more than was obtained at Coldbrook, utilizing flood flows only as contemplated by the Joint Commission. In other words, it was a question of going to Coldbrook with a large conduit built at a low level, securing 33 million gal. per day from flood flows only, of which Worcester's share would require high-lift pumping, or building a high-level reservoir on the headwaters of the river, securing from 45 to 50 million gal. per day, all of which will flow by gravity to either supply. The first procedure was estimated to cost approximately $12 000 000 and the other $14 000 000.

The latter figure included an allowance of $4 000 000 for constructing a compensating reservoir on the river near the village of Coldbrook, in order to replace for industrial uses the equivalent of the water diverted for water-supply purposes. Of the average flow of substantially 100 million gal. per day now flowing in the river at Coldbrook, approximately one-half will be diverted for water-supply purposes, reducing the existing flow at that point to, say, 50 million gal. per day. Practically all of this flow however, will be retained and controlled by the proposed compensating reservoir so that it can be made available as needed for power uses. A considerable portion of the present uncontrolled flow is wasted in freshets and floods without serving any useful purpose and we estimate that, with the 50 million gal. per day of controlled water, the industrial users will actually secure a larger total amount of power from the river than is now obtained under existing conditions.

Some question has been raised regarding the probable color of the water from the proposed North Ware reservoir. It is true that there are some swampy areas which would be flooded and which now impart a color to the Ware River water somewhat higher than that of Wachusett water. It would seem to make little difference, however, in this respect whether the supply was taken from this source or from the flood flows at Coldbrook, as proposed in the alternative plan. In fact, we feel that prolonged storage in a reservoir holding 26 billion gal. would greatly improve the color of the water. Furthermore, under this plan the supply could be fed to the Worcester and Wachusett reservoirs in relatively small but continuous amounts, whereas, if obtained from the flood flows at Coldbrook, the Ware water would have to be absorbed in large doses whenever it was available.

Of course, if the Ware River water is taken from the upper sources, as proposed by us, and delivered to the present systems through a high-level tunnel built especially for that purpose, it would be necessary to construct an entirely independent tunnel from the Wachusett reservoir in case subsequently it was found necessary to go to the Swift River for a future addition to the supply. The query may therefore suggest itself, if we ultimately must go to the Swift, why not build the required aqueduct now as far as Coldbrook,—which is substantially one-half the distance from the Wachusett reservoir to the proposed Swift reservoir, — taking the Ware water at that point as proposed by the Joint Commission rather than to construct a separate aqueduct to the North Ware supply, which will necessitate the building of another tunnel in the future for the full distance? In other words, why spend $14 000 000 to develop the Ware above Barre Falls when $12 000 000 would pay for the necessary works to secure the water at Coldbrook and at the same time provide one-half the length of the future aqueduct needed to reach the Swift supply?

The answer to this question is comparatively simple. In order to take the flood flows on the Ware at Coldbrook it is necessary to build the aqueduct for its entire length of a much greater capacity than would be required merely for delivering the Swift supply to Wachusett. Instead, therefore, of a conduit 12 ft. 9 in. in diameter, as proposed by the Joint Commission, a 10-ft. tunnel would be sufficient for the purpose in case the Ware water was independantly taken, as proposed by us. Since the cost of such a tunnel varies approximately as the three halves power of the diameter, we found that about $6 000 000 would be saved in the cost of this item alone in case the Swift supply was ultimately developed. Furthermore, since the supply to be obtained from the proposed North Ware reservoir is at least 14 million gal. per day greater than that to be secured from the flood flows at Coldbrook, the subsequent extension to the Swift could be deferred for from four to five years longer than if the lesser supply was used. The saving of the interest upon the investment, made possible by this delay, amounts to another $8 000 000. It will be seen, therefore, that these two savings alone will pay the entire cost of the proposed North Ware supply.

In addition, the high-level supply will eliminate pumping for all time in connection with Worcester's supply, and if this item were to be capitalized it would amount from perhaps $1 000 000 at the beginning to $12 000 000 by the time the city required the entire supply. Also, it is important to remember that our plan adds 26 billion gal. of permanent storage to the combined systems which the alternate plan does not, and through the medium of the proposed compensating reservoir we leave the power-users on the river in a better position than they now occupy with respect to amount of usable power.

I might also add that in our opinion it is not yet conclusive that there will necessarily be occasion to extend the works to the Swift for at least many years, if ever. The recent decline noted in the rate of population increase raises grave doubts concerning the future need for such a very substantial increase of supply. Until there is some more definite evidence of the need for this large increase in capacity in the not distant future, it would seem to be the part of wisdom to proceed with the utmost caution before committing the community to such a great expenditure, a large part of which may remain an idle investment over a long period.

It was our conclusion therefore that a moderate expenditure at this time for the developing of the North Ware supply would meet the combined requirements of the metropolitan district and the city of Worcester for the next fifteen years or more, after which the Assabet supply could be brought in at an expense which, even including the cost of filtering the entire supply, would represent an outlay less than one-third of that required to develop the Swift project; while if this step were followed at a later date by the utilization of the Ipswich River, the total amount of water secured from the three sources would be sufficient in all probability to meet the requirements for the next forty-five to fifty years, at the expiration of which time it could be determined whether or not the Swift or some other project was most desirable for the further extension of the supply. Meanwhile the piecemeal development would permit very substantial savings in interest charges upon an idle investment which would otherwise result in case the $60 000 000 Swift project was undertaken at this time.

Some difficulty was encountered in determining the most equitable method by which to apportion the present and future expense incident to constructing and operating the proposed joint development on the North Ware between the metropolitan district and the city of Worcester. Our recommendation in this respect has been the subject of much adverse criticism in some quarters. It has been gratifying, however, to observe that many of the interested parties who have been disposed to question its fairness have, in the light of subsequent study, reversed their original judgment and have approved the proposed financial plan as substantially sound.

At the present time the metropolitan system consumes eight times as much water as does Worcester. We proposed therefore that the metropolitan district should contribute eight-ninths and Worcester one-ninth

of the cost of development and of subsequent operation, each sharing in ownership in similar proportion. It so happens that this division of the proposed new supply gives each of the parties an increase of 25 per cent. of its present supply.

It is recognized, however, that this source must be relied upon in the future to supply Worcester with all of its additional water needs, and we anticipate that its initial share of one-ninth will supply its requirements only for from twelve to fourteen years, after which it will be obliged to take over a larger share of the total supply in order to meet its increasing demands for water.

For this reason we made provision in the legislative bill that when that time should arrive, Worcester should have authority to purchase from the metropolitan district another one-ninth of the supply by reimbursing the district for its original cost. Meanwhile the district would have enjoyed the use of this portion of the supply at a net cost of the interest only on the expense of its original development plus operating charges. Thereafter Worcester would be required to pay two-ninths of all current charges.

This procedure would be continued until Worcester finally owned the entire supply, by which time of course the metropolitan district must have developed its next source of supply, leaving Worcester in complete possession of the North Ware system. By this time the district would have received back every dollar of its original investment in the North Ware development and would be entirely relieved from further expense of every nature in connection therewith.

An examination of this arrangement will show that Worcester and the metropolitan district will pay the same identical price for each one million gal. belonging to it during their joint participation, and so long as the district is able to secure water from this source it will be relieved from the investment charges incident to an equivalent supply elsewhere.

The metropolitan district can secure additions to its system from several possible sources at reasonable costs of development, whereas Worcester, because of its high altitude, is limited practically to the North Ware supply unless it is to assume very burdensome costs for high-lift pumping. It is this economic consideration which makes it incumbent upon the district ultimately to yield this supply to Worcester, as the city may require it. So far as now appears, however, it will be at least one hundred years before the rights of the district to at least some portion of this supply shall entirely cease.

These, then, are the circumstances under which the Legislature must make its choice. Shall it settle this question substantially for all time by directing the expenditure of $60 000 000 to develop the Ware and Swift rivers, as proposed by the Joint Commission, or shall it meet the requirements of the next fifteen years or more by a comparatively modest investment of $14 000 000 on the North Ware, made available out of the savings effected by postponing the larger project and by reducing the size of the

subsequent aqueduct required by reason of the separate taking of the Ware waters. Furthermore, it must decide whether or not the Assabet and Ipswich sources are worth conserving and, if so, it must invest some ten or eleven million dollars in the purchase of land and rights in order to assure their future availability.

While our commission reached conclusions somewhat at variance with those of the Joint Commission, I am glad to have this opportunity to pay my tribute to the general excellence of their proposal from a strictly engineering standpoint. This result was inevitable in view of the character and ability of the men who constituted the commission and of the engineers who advised them. Many circumstances are apparent today which were unseen at the time when the earlier report was presented. This is particularly true with respect to population growth and per capita consumption. If we felt justified in ignoring economic considerations as they affect the problem today, there might be much less difference between us than now exists.

REPORT OF THE METROPOLITAN WATER SUPPLY INVESTIGATING COMMISSION

To the Honorable the Senate and House of Representatives, of the Commonwealth in General Court assembled.

The undersigned, members of the Metropolitan Water Supply Investigating Commission, appointed by the Governor on August 20, 1924, under the provisions of chapter 491 of the Acts of 1924, submit the following conclusions and recommendations which are treated more in detail in subsequent portions of this report.

1. The present sources of water supply of *satisfactory quality*, available for the needs of the Metropolitan District, can be depended upon to furnish an average output of not more than 119 mil. gal. per day during a series of exceptionally dry years such as frequently occur, whereas the district is now consuming approximately 130 mil. gal. per day and is called upon for additional amounts for other communities, with the probability that an even greater total amount will be needed in the immediate future.

2. In addition to this amount of good water there is also available an existing supply of some 26 mil. gal. per day obtainable from the South Sudbury system, the present natural quality of which is so unsatisfactory that for many years past it has been used only in extreme emergencies and for short periods when there was no other alternative. This supply can be made equally satisfactory, or better than that now used, by constructing suitable purification works at an expenditure of approximately $3 500 000, which will thereafter assure to the district a total safe capacity of 145 mil. gal. per day, sufficient according to our estimates to meet the probable water needs of the district until about the year 1929. Before that date, therefore, there must be developed some new supply if the danger of a probable water shortage is to be avoided, and the period required for constructing such works will probably be not less than four years under the most favorable circumstances.

3. The city of Worcester is in an even more critical state respecting its water supply than is the Metropolitan District, since it is already experiencing an actual shortage of supply and has been compelled to purchase from 5 mil. to 6 mil. gal. per day from the Metropolitan District for several months past, and to pump the same from the Wachusett Reservoir into its own system. This water used by Worcester is in addition to the 130 mil. gal. per day now being consumed by the district itself.

4. Additional water, suitable for the future needs of the Metropolitan District and of Worcester, may be secured by developing the Ware and Swift rivers for that purpose, as originally suggested as a future possibility

at the time the metropolitan system was created, and as recommended still more recently by the Joint Board, so called, which reported upon the subject in the year 1922; or otherwise various smaller developments may be utilized which can be added to the system from time to time in the future as the demand for greater quantities of water occurs.

5. The Ware and Swift river project as recommended by the Joint Board would, if carried out, more than double the present capacity of the existing supply, including that proposed to be reclaimed by filtering the South Sudbury water, and would care for the combined needs of the Metropolitan District and of Worcester for perhaps as much as seventy-five years into the future. This source would yield a water of excellent natural quality, and its cost *per mil. gal. of capacity* might be as low as that of any other source or sources which can be suggested as substitutes. The entire investment, however, would have to be made substantially at once for an amount of water which would not be required for many years hence, or possibly never, if by any chance the growth in population were for any reason to cease or decline.

6. The taking by the Metropolitan District of the waters of the Swift and Ware rivers, together with the large areas of land required for reservoirs and protective measures, is strongly objected to by the communities in that section of the State because of what is deemed to be an unnecessary encroachment upon existing local rights and benefits pertaining to these natural resources. Also, the proposed method of utilizing this source would not meet in a satisfactory manner the requirements of the city of Worcester for an addition to its present supply, since all of the water which that city might secure from such a development would have to be elevated several hundred feet by pumping, and its taking would necessarily be subject to such restrictions and regulations as might be imposed by the Metropolitan District.

7. There is, however, a possible solution of Worcester's water supply problem which would seem to be advantageous alike to that city and to the Metropolitan District. By constructing a dam across the Ware River in the vicinity of Barre Falls, a large reservoir would be created in the valley above that point which would have a capacity of 45 mil. gal. per day which could be made to flow by gravity either to some of the existing reservoirs of the Worcester system, to the Wachusett Reservoir or to both. Since the amount of water which would be made available by this means would be considerably in excess of that required by the city of Worcester for a very long future period, there would remain during that time a substantial surplus which could be utilized by the Metropolitan District to augment its present supply and thus to defer the occasion when additional sources would be required for the enlargement of its own system. The estimated cost of developing this supply is $14 000 000.

8. In addition to the supply obtainable from the North Ware, it will be possible, whenever it is needed, to secure 47 mil. gal. per day of addi-

tional supply by diverting certain branches of the upper Assabet River into the Wachusett Aqueduct which passes through the watershed of that river on its way to Sudbury Reservoir. The cost of such a development will be approximately $8 500 000.

9. When the time comes for securing more water than those two sources are capable of delivering, the Ipswich River above the town of Topsfield can be developed as a third source of supply capable of yielding 80 mil. gal. per day, 30 mil. gal. of which may ultimately be required for the water needs of communities in or adjacent to the Ipswich valley. The remaining 50 mil. gal. per day could be pumped to the metropolitan system in the vicinity of Spot Pond. The total cost of this development at present prices would be in the neighborhood of $19 000 000.

10. The Hobbs Brook Reservoir of the city of Cambridge water supply can be greatly increased in size by raising the present dam some 30 ft. If this were done it could be kept full by pumping water from the lower Sudbury River during seasons of flood and by such means the capacity of the supply might be increased 30 mil. gal. per day. The cost of this development would be about $12 000 000.

11. The total additional supply which can ultimately be secured by developing successively the North Ware, Assabet, Ipswich and Hobbs Brook sources will be 202 mil. gal. per day, and the aggregate cost approximately $53 500 000. These figures compare with approximately 200 mil. gal. per day obtainable from the Swift, Ware and Millers rivers at a cost, as estimated by the Joint Board in its 1922 report, of $60 000 000.

12. The water obtained from the Assabet, Ipswich and Hobbs Brook sources would require filtration before using, while that of the North Ware supply, if used in considerable quantity, might tend to lower slightly the present quality of the Wachusett water with which it would necessarily mix in passing through the system. On the other hand, unless very considerable sums are expended in the near future in the purchase of property adjacent to the Wachusett Reservoir, for the preservation of the purity of the supply, it is doubtful if resort to filtration of that water can be much longer deferred.

13. The Quinebaug River has also been considered as a possible source of future supply. Considerable quantities of water of excellent quality might be obtained from this source at a cost comparable with other supplies studied, but since sufficient water is obtainable from nearer sources, no recommendation is made at this time with respect to this supply.

14. Aside from the matter of securing some new source or sources of supply, there is also involved the important question of bringing the additional water thus obtained into the Metropolitan District. Existing demands require the full capacity of available conduits from the Weston terminal of the Weston Aqueduct to the centers of distribution. Certain engineering studies which have been made in the course of this investigation indicate the desirability of constructing a deep-pressure tunnel in the underlying rock between the Weston terminal and a point in or near the

city of Everett. The estimated cost of such a tunnel is $17 000 000. In addition, some present deficiencies of capacity in certain sections of the Weston Aqueduct itself now require correction at an estimated expense of $700 000.

15. In view of all the facts outlined, we recommend:

(*a*) That a special construction commission be created with authority to improve and increase the present water supply of the Metropolitan District and of the city of Worcester.

(*b*) That the commission should immediately construct a suitable filtration plant for making available the waters of the South Sudbury system.

(*c*) That the commission also should proceed immediately with the construction of a reservoir on the upper Ware River for the joint use of the city of Worcester and the Metropolitan District.

(*d*) That an agreement should be entered into between the city of Worcester and the Commonwealth whereby the latter shall construct the said reservoir and its necessary appurtenances, the city contributing one-ninth of the actual cost of same in return for the right to take one-ninth of all the water thereby made available, with the further privilege of taking from time to time in the future additional amounts of water when needed, in increments of one-ninth each, paying therefor one-ninth of the original cost for each one-ninth of the supply of water so taken, and in addition contributing to the annual cost of maintenance and upkeep in such proportion as its taking of water bears to the capacity of the entire supply.

(*e*) That the commission be authorized to purchase land at a suitable point along the Weston Aqueduct for the location of a future filtration plant of sufficient capacity to filter the amount of water capable of being carried by said aqueduct.

(*f*) That the commission be empowered to purchase or take by right of eminent domain such land, rights, easements or other property within the watersheds of the Assabet and Ipswich rivers as it may determine to be necessary for the proper protection of these sources against future encroachment by private interests and for preserving the sanitary quality of their waters.

(*g*) That the commission be instructed to study and to report their recommendations to the General Court on or before December 1, 1926, as to the need, location and estimated cost of delivering the future water supply to the distribution system of the Metropolitan District either by pressure tunnel or by pipe lines.

(*h*) That the Legislature appropriate the sum of $27 500 000, and that proper authority be given the said commission for expending the same in carrying out the foregoing recommendations.

Organization of Commission.

The commission met for organization on September 3, 1924, the Governor having previously designated Charles R. Gow as chairman.

Raymond C. Allen of Manchester, Mass., was appointed to act as secretary of the commission in addition to other duties of an engineering nature which were assigned to him.

Allen Hazen of New York, a celebrated authority of international reputation upon the subject of water supply, was engaged by the commission as its consulting engineer, and he was authorized to call into conference from time to time other engineers especially qualified to advise with him upon specific matters with respect to which they possessed information pertinent to the investigation. Acting under this authority, Mr. Hazen has at frequent intervals conferred with Mr. Leonard Metcalf of Boston, likewise well known throughout the country as an expert upon the question of water supply, with particular reference to questions of population growth and water requirements in Massachusetts, studies of the metropolitan distribution system, and the present use of water for power and process purposes along some of the streams considered as possible sources of additional supply.

The engineering work involved has consisted of a complete review of all previous studies heretofore made upon the subject, together with an investigation of every available new source of supply which appeared to offer any promise as a solution of our problem.

Much original survey work has been required in order to secure the necessary data upon which to predicate an intelligent opinion. Borings have been made and much reconnaisance work has been done in connection with the study of the several sources considered.

Upon the basis of the information submitted by our engineer, together with our own deliberations and conferences, we are able to submit the following observations and conclusions.

History of the Metropolitan Supply.

Thirty-two years ago the Legislature directed the State Board of Health to investigate and report upon the question of a water supply for the city of Boston and surrounding cities and towns known as the Metropolitan District. After a careful and extensive inquiry into every possible source then available, a suggested program for the progressive development of an adequate and satisfactory water supply sufficient for an indefinite future period was recommended to the Legislature, and the initial step in its construction was authorized by that body in the year 1895.

As a consequence of this legislation, a commission known as the Metropolitan Water Board (since merged in the present Metropolitan District Commission) was created, and proceeded under the terms of the act to take over the Cochituate and Sudbury works of the city of Boston water supply, together with certain other existing facilities and appurtenances, and in addition to construct the present Wachusett Reservoir on the south branch of the Nashua River above the town of Clinton, together

with the necessary aqueducts and distribution mains which should make the water available for the needs of the district.

At the time of its adoption this portion of the comprehensive program was deemed sufficient to supply the water needs of the district for a period of only twenty years, or until 1915, at which time it was anticipated the works would be enlarged, first by utilizing the waters of the Assabet River and subsequently through extension in a westerly direction by the construction of a large reservoir on the Ware River in the vicinity of Coldbrook, to be followed at a still later date by the development of additional supplies upon the Swift and Deerfield rivers whenever the increasing demands for water in the Metropolitan District should make such action necessary. Accordingly the aqueducts and other facilities for bringing the Wachusett water to the district were designed of ample capacity to care for a substantial portion of this proposed future supply from the more remote sources.

The metropolitan supply as originally provided has served the water needs of the district for a much longer period than was then anticipated, due to causes that will be referred to later on, so that the expected use of the Assabet supply and extension to the westward has thus far been deferred.

In the year 1919 the Legislature directed the State Department of Health and the Metropolitan Water and Sewerage Board (the latter since merged in the Metropolitan District Commission), acting jointly, to investigate the water supply needs of the entire Commonwealth, and to make recommendations in connection therewith.

This Joint Board, so called, devoted the major portion of its inquiry to the needs of the Metropolitan District, reviewed in large measure the investigations of the earlier board of 1893, confirmed in general its original judgment with respect to a program for future extensions, and, except for the dissenting opinion of one member, recommended immediate action in proceeding with the second stage of its development with some modification as to detail. Mr. James A. Bailey, then chairman of the Metropolitan District Commission and a member of the Joint Board, filed a dissenting report, maintaining that the present supply was adequate for a considerably longer period, was capable of further conservation through additional elimination of waste, and that therefore the proposed expense incident to the contemplated extension at that time was unwarranted. We have carefully reviewed and considered the conflicting opinions and reasoning presented in the majority and minority reports, respectively, and with regard to the principal items of disagreement submit the following comments:

Capacity of Existing Sources.

The primary source of all water supply is rainfall, and the amount of precipitation which occurs in any given locality varies through wide limits from year to year. To the extent that the excessive precipitation of one year may be caught and stored in huge reservoirs for use in subsequent

years of deficient rainfall, this variation in the annual yield of a given water supply may be somewhat reduced. It is not practicable, however, for many reasons, to construct reservoirs of the magnitude required to retain for future use the entire rainfall of a given area over a period of years, and therefore the ability of any supply to meet the water needs of the community dependent upon it is measured not by its maximum nor by its average yield, but rather by the minimum amount which it may be relied upon to furnish during a series of dry years, since the demand for water is quite as great, or more so, in seasons of drought as during any other period. A storage reservoir may therefore overflow for considerable periods during years of average or excessive rainfall and still be incapable of supplying the water needs of its users in an unusually dry series of years such as are known to recur at more or less regular intervals.

In determining the safe yield of a given supply there are many factors to be considered, such as the total volume of storage available, its relation to the area of the watershed contributing to it, the amount of run-off to be expected from the particular watershed, the minimum rainfall to be anticipated in that locality, the depth to which the reservoir may safely be drawn down, and other minor elements entering into the case. It should not be a matter of surprise, therefore, if equally good authorities should be found to differ in their independent estimates of the safe yield of the present metropolitan supply.

The ratings given to the capacity of the present supply, both by Mr. Bailey and the engineer for the Joint Board, represent the minimum amount of water which it is likely to yield during the driest period of years which may reasonably be anticipated on the basis of recorded observation and experience.

Mr. Hazen, our consulting engineer, on the other hand, has adopted a somewhat different line of reasoning in the determination of the safe yield of both the present and suggested future supplies. He adopts as the basis of safe yield the amount of water which the supply can be depended upon to furnish in each of ninety-five years out of every one hundred; that is to say, there are likely to be five years in every one hundred during which the supply will fail to yield this amount. This will not necessarily result in a deficiency of supply, however, in these particular years unless their occurrence should coincide with the last years in its life, since during the early period of use the demand upon the supply will always be considerably less than its minimum capacity, and it is not, therefore, until the consumption demands begin to approach the ultimate capacity of the supply that there is any danger of actual shortage of water from this cause. In fact, it is not until the consumption exceeds something over 90 per cent. of the estimated yield of the supply that the occurrence of an excessively dry year may result in a water shortage. It is expected that when this point has been reached in the use of the supply, new developments will be under way looking to a further increase, and in any event the danger of the occurrence of an actual

hardship entailing emergency measures to overcome a shortage of available water, depending as it does upon the coincidence of one or more unusually dry years with the final period of dependence upon the supply, may well be minimized as a factor of vital importance.

In Mr. Bailey's minority report, the safe yield of all present sources is given as 160 mil. gal. per day, whereas the engineer for the Joint Board, uses a figure of 154 mil. gal. per day as the net available amount, after making certain deductions for water lost to the district through diversion elsewhere under statutory requirements and otherwise.

It appears, however, that not all of this water is of satisfactory quality for public consumption at the present time, and for many years past the entire supply for the district, except on rare occasions, has been drawn exclusively from the Wachusett Reservoir and two reservoirs in Framingham on the Sudbury River, known, respectively, as Sudbury Reservoir and Framingham Basin No. 3, into one or both of which the Wachusett water flows before entering the aqueducts which lead to the district.

The safe yield of these usable sources has been determined by Mr. Hazen in accordance with the method previously outlined to be 119 mil. gal. per day, and since the Metropolitan District is now using an amount considerably in excess of this total, this supply is obviously inadequate to meet the demands of an extremely dry period should one occur in the immediate future.

There are available, however, in addition, two other existing supplies, — the South Sudbury system and Lake Cochituate. Either of these sources could be utilized today in an emergency, although in their present state their waters are decidedly objectionable from a hygienic standpoint. Much of the water of the South Sudbury system is collected from swampy areas and is therefore highly colored; also, certain industrial wastes contribute pollution to some of the streams and feeders which supply water to the reservoirs. There is also an existing population upon the watershed of this source considerably in excess of that usually deemed safe under modern sanitary conditions.

Investigations are now in progress by the Metropolitan District Commission looking to the recommendation of a suitable filtration system for purifying the water furnished from this source, and, provided such filters are installed, it should be possible, according to Mr. Hazen's calculations, to obtain a dependable yield from this supply alone of 26 mil. gal. per day. This is unquestionably the quickest and most logical method of meeting the immediate needs of the district for additional water of satisfactory quality, and no time should be lost in our opinion in authorizing the construction of these works if the public health and welfare of the community is to be properly served.

It is our opinion that Lake Cochituate should no longer be included as a regular component part of the metropolitan supply. It has now upon its watershed a population considerably in excess of 1 000 to the sq. mile,

a factor which renders its water liable to serious contamination, and analyses made from time to time indicate a progressive deterioration in its quality. This water is also subject to disagreeable tastes and odors, especially during the summer months, which might be somewhat difficult to eliminate completely even by filtration. It is recommended, therefore, that this supply be reserved permanently merely as an emergency source, and that provision be made for sterilizing the water by chlorine treatment whenever at rare intervals there may be occasion to use it for short periods in order to supplement the present supply.

Assuming that the South Sudbury supply is to be filtered in the immediate future, there will be available to the district from all existing sources an aggregate minimum supply of 145 mil. gal. per day of water of satisfactory quality.

By holding Lake Cochituate in reserve there will always be available an additional emergency supply capable of furnishing approximately 12 mil. gal. per day in the comparatively short periods during which it would be utilized.

The 145 mil. gal. per day now available exclusive of Cochituate water is only 15 mil. gal. in excess of the present consumption requirements of the district, and it should be borne in mind that suitable additions to the supply will require a construction period of at least a few years so that the requirements of the future must necessarily be anticipated to that extent.

Probable Life of Present Supply.

In order to estimate the probable life of a given water supply it is necessary to make some arbitrary assumptions as to the future rate of growth of the population which it is to serve and the expected change, if any, in per capita consumption of water. It should always be distinctly understood that there is absolutely no method available by which these elements of the problem may be determined in advance with even approximate accuracy. The actual results of growth and consumption frequently vary over wide limits from preliminary forecasts, even when the latter are based upon a most careful and intelligent study of all the attending circumstances. Nevertheless, such estimates must of necessity be made in order to arrive at any conclusion respecting the requirements of the case.

When the present works were recommended in 1895 it was estimated, as previously stated, that the initial development would care for the needs of the district for twenty years only. At that time the population was increasing at a high annual rate that showed no evidence of subsiding. Referring to the subject of future growth, Mr. Frederick P. Stearns, chief engineer for the State Board of Health in 1895, who conducted the original engineering investigations and subsequently supervised the construction of the works, said in his report of that date:

In addition to the basis for estimates furnished by the past growth of the community under consideration, and of other large communities,

we may use our judgment as to whether the causes which have induced growth in the past are likely to operate more or less effectively in the future. In the case of Boston I have not found any reason to modify the estimate of future population based upon its past growth and the growth of other cities. There has been a tendency to predict a slower growth for Boston in the future, because of its remoteness from the sources of raw materials and the principal markets of the United States. In opposition to this prediction we have the fact that the growth of the district has been very much more rapid during the last nine years than in any previous nine years; and it can hardly be said that the conditions are any less favorable for rapid future growth at the present time than they were nine years ago.

Based upon this apparently sound reasoning Mr. Stearns prepared a table of probable future population figures upon which he predicted the expected growth in water requirements of the district. At the outset, several cities and towns which were expected to enter the district failed to do so, thus reducing substantially the initial population figure, while shortly thereafter the rate of increase in population declined materially, thus upsetting completely the accuracy of his earlier predictions. Instead, therefore, of requiring a further extension of the work in 1915, as originally anticipated, the initial development has supplied the water needs of the district to date, and apparently the limit of its capacity to meet the demands upon it will not be reached for a few years yet to come, after certain portions, not now in use, are restored to service.

A revised estimate of the probable future growth of population in the metropolitan area from 1920 to 1970 was made by the chief engineer of the Joint Board, and appears on page 57 of their report. This estimate indicates a total population by the year 1970, for the cities and towns now using metropolitan water, of approximately 2 500 000.

For the first five years of the period, however, that is, from 1920 to 1925, this forecast has also been found to be somewhat liberal, the estimated gain in population for these years having proved to be 28 per cent. in excess of the actual increase. If the same per cent. of error should be found to apply for the remaining years of the estimate period, the forecast of 2 500 000 for the year 1970 would be reduced to about 2 218 000.

Independent estimates of future growth have been made by our consulting engineer, which indicates a population of the present water district in the year 1970 of 2 140 000.

Once again the fact should be emphasized that all such estimates of future population must necessarily be based upon more or less arbitrary assumptions which may ultimately prove to be grossly inaccurate. There are many factors in the problem, however, which incline us to the belief that there may be more likelihood under present conditions of overestimating the future growth of population in the Metropolitan District than there will be of understating it. We are disposed, therefore, to believe that the Joint Board's estimate of 2 500 000 may be assumed to be the very maximum figure which may be expected for the year 1970, and that our own

engineer's forecast of 2 140 000 is not necessarily the minimum number to be anticipated.

Estimates of future increase in per capita consumption of water are similarly unsatisfactory and unreliable. It is undoubtedly true, as was pointed out in the Joint Board's report, that there is a pronounced tendency for individual water requirements to increase from year to year, although the rule is by no means universal in its application. So far, the per capita use of water in the Metropolitan District has been held down by the progressive installation of meters, with the result that the present individual consumption is only slightly larger than when the works were installed thirty years ago. On the other hand, since the water services of the district are now 95 per cent. metered, it seems improbable that much further reduction can be expected to result from this cause alone. There are reasons for believing that the per capita figure may increase somewhat in the future, based upon observed results elsewhere under similar circumstances, unless other means can be devised to check the tendency. It is probable that continuous and thorough inspection may be made to eliminate some of the waste which probably exists along the many miles of distribution pipes and conduits, but it is doubtful if this saving will be substantial in amount. Increases in the future cost of water to the Metropolitan District, which now seem more or less inevitable, will in all probability also tend to restrict consumption somewhat, and this may prove to be an important factor in preventing a rapid growth in the future per capita consumption.

The Joint Board in its estimate of the future water requirements of the district assumed a yearly increase of one gallon per capita in the daily consumption after the year 1925, starting with the figure of 105.5 gal. which was the recorded average per capita consumption for the year 1920 at which date the estimate began. As a matter of fact, the actual per capita figure dropped in the subsequent years, being only 95 gal. in 1924, a result due no doubt to the increase in the percentage of metered services from 75 per cent. to 95 per cent. during that particular four-year period.

If the per capita consumption can be maintained at not more than 100 gal. per day, it would appear that the present available supply of water, including the filtered South Sudbury system, will on the basis of our own consumption forecast be sufficient to supply the present users until the year 1929, or only three years hence. It appears therefore that the district is already confronted with the possibility of a shortage of satisfactory water, since at least four years will probably be required to develop a suitable addition to the present supply. In the meantime, should a cycle of dry years occur three years hence, it will be necessary to use water of an inferior quality until such time as the new supply can be made available.

Possible Additions to Metropolitan Water District.

At present there are fifteen cities and towns within a 10-mile radius of Boston, which constitutes the Metropolitan District, that have not availed

themselves of their legal right to take water from the Metropolitan supply. These are Cambridge, Canton, Braintree, Dedham, Hingham, Hull, Lynn, Needham, Saugus, Wakefield, Waltham, Wellesley, Weymouth, Winchester and Woburn. It is not probable that Lynn and Saugus will require water from the metropolitan supply for many years to come, if ever. Similarly, the needs of Hingham and Hull will probably be supplied from existing sources until some years hence. There is a strong probability, however, that the remaining eleven municipalities may, in the not distant future, require some assistance from the Metropolitan Water District in augmenting their present inadequate or unsatisfactory supplies.

To these prospective numbers should possibly be added the towns of Norwood, Reading, Weston and Westwood, which, while not located within the 10-mile zone, will very likely need assistance before long in obtaining additional water, whereas the only opportunity for securing the same appears to be that afforded by the Metropolitan supply.

It is reasonably certain that the next occurrence of a severe dry spell will find the majority of these fifteen municipalities without an adequate supply of water, so that their excess requirements over and above the capacity of their present sources must be provided out of the existing surplus of the Metropolitan supply.

Water Requirements of the City of Worcester.

In addition to a possible outside draft upon the present supply from the last-named cities and towns, it should be noted that the city of Worcester is already drawing heavily upon the Wachusett supply in order to secure an adequate amount of water to meet current demands, and this commission is charged with the duty of recommending a permanent solution of the water requirements of that city as well as for the Metropolitan District.

For some months past the city of Worcester has been pumping at the rate of 6 000 000 gal. per day from the Wachusett Reservoir because of a similar deficiency in the amount of supply furnished by its own water sources. It is to be observed, however, that its most recently constructed reservoir, Pine Hill, has not yet had an opportunity to fill, and that when this new source is available the shortage in the city's supply will, for a brief period, be eliminated.

Even with this addition to its water resources, giving a total capacity of some 20 mil. gal. per day, the water needs of the city will probably exceed the capacity of the local supply by the year 1930 or earlier, and a new source of supply must be secured before that time.

It appears, therefore, that in any consideration of the probable remaining life of the present metropolitan supply there must be included as a factor the possible requirements, in excess of their existing resources, of the cities and towns adjacent to the Metropolitan District and of the city of Worcester.

Probable Growth in Demand for Water.

The following table has been prepared to indicate the expected future growth of population of the combined communities which may be expected to participate in whole or in part in the metropolitan water supply within the next ten years. In addition to the cities and towns comprising the present water district there are included the fifteen cities and towns previously enumerated; the city of Newton which, while a member of the Metropolitan Water District, as yet uses but little water from that supply; the town of Brookline, which now obtains only its excess demands from the metropolitan system, and the city of Worcester.

Future Population and Water Consumption of Metropolitan District, Including Newton and Brookline, together with Fifteen Surrounding Municipalities and the City of Worcester.

Year.	Estimated Population.	Estimated Consumption (m.g.d.).
1925	1,890,456	182,000,000
1930	2,020,000	202,000,000
1935	2,150,000	221,000,000
1940	2,270,000	240,000,000
1945	2,390,000	260,000,000
1950	2,510,000	280,000,000
1955	2,625,000	302,000,000
1960	2,740,000	325,000,000
1965	2,850,000	350,000,000
1970	2,960,000	375,000,000

The aggregate capacity of the combined sources of supply now available for the needs of these several municipalities is as follows:

	m.g.d.
Present metropolitan supply	145,000,000
Newton and Brookline supplies	10,000,000
City of Worcester supply	20,000,000
Fifteen surrounding cities and towns	23,000,000
Total	198,000,000

Worcester's Rights in the Wachusett Watershed.

Certain portions of the Wachusett watershed were originally conceded to be the logical ultimate source of water supply for the city of Worcester, although at the time of their taking by the metropolitan authorities they were not needed for local purposes, and the date of this future requirement was problematical and at least remote. A particular area of about 9½ sq. miles, located in part in the towns of Holden, Paxton and Rutland, was definitely recommended by the engineer of the original board which reported in 1895 to be dedicated to the future needs of the city of Worcester. This

area has since been taken over by the city and now supplies the water which is received and stored in the new Pine Hill Reservoir.

The Metropolitan Water Act, so called, also known as chapter 488, Acts of 1895, as amended by chapter 456 of the Acts of 1897, provided in section 22 as follows:

The towns of Clinton, Sterling, Boylston, West Boylston, Lancaster, Holden, Rutland, Princeton, Paxton and Leicester, *and the city of Worcester*, may take from the south branch of the Nashua River, above the dam of the proposed reservoir on said river, so much of the water thereof as they have already been or may hereafter be authorized by the legislature to take, for supplying their inhabitants with water, and in case either of the towns of Lancaster, Holden, Rutland, Princeton, Paxton or Leicester, or the city of Worcester, shall so take water, it shall pay to the commonwealth, to be paid into the sinking fund for said bonds, a fair proportion of the cost incurred by the Commonwealth for said water, and if the water is taken from the river above said reservoir it shall pay in addition a fair proportion of the cost of maintaining the purity of said water above the point of taking; and if the water is taken from said reservoir it shall pay in addition a fair proportion of cost of maintaining the purity of said water and of the cost of constructing and maintaining said dam and reservoir. Said proportion shall be determined by the engineer of said board and an engineer to be appointed by the city or town, and if they cannot agree, the proportion shall be determined by a master to be appointed by the supreme judicial court on the petition of either party interested, and the report of such master made and accepted by said court shall be final and binding on all parties.

It is to be noted that the right of any of the several municipalities to take water from this source is made subject to the approval of the Legislature, but such approval is necessary in any event when a community seeks to take water from without its own boundaries. We are strongly of the opinion that the wording of this section was deliberately intended to preserve the rights of Worcester and the enumerated towns to secure their future water supplies from this source whenever the necessity for additional quantities of water arose. Assuming this to be the case, it must be conceded that an implied contract was entered into between the city of Worcester and the Commonwealth guaranteeing relinquishment by the State to the city of such portion of the supply as might later be required by the latter for supplying the needs of its inhabitants. We are firmly convinced, also, that the dictates of good faith and fair dealing demand a frank acknowledgment of this moral obligation.

It is true that, acting under this provision of the act, the State has already relinquished to the city of Worcester some 9 sq. miles of this territory for water-supply purposes, and this area has been developed by the city and now furnishes a portion of its water supply. The act itself, however, prescribes no limit to the prior right of the several communities to secure their necessary additional supplies from this source, even though ultimately they might require the diversion of the entire supply furnished by the river above the dam.

Acting upon this assumption, the city of Worcester recently petitioned the Legislature for its approval of the taking of the waters of the Quinapoxet River, one of the feeders of the Wachusett system, and the diversion of these waters for the purpose of an additional supply for that city. This proposal was strongly opposed by the Metropolitan District authorities upon the ground that it would divert upward of one-sixth of the entire Wachusett supply and would compel the Metropolitan District to seek a new supply at once in order to replace the amount thus lost. It was stated by Mr. James A. Bailey, in his dissenting report as a member of the Joint Board, that under the provisions of the act quoted above, Worcester would be compelled to pay only about $400 000 for water worth at a capitalized value of $4 000 000, and he added:

the Metropolitan Water District can better afford to make a gift of millions of dollars to the city of Worcester than to have Worcester take from the district the watershed sought by her.

Recognizing the justice of the claim which Worcester has relative to Quinapoxet River, we are of the opinion that from an economic standpoint it is desirable that the Metropolitan District coöperate with Worcester in the development of an entirely new supply under such equitable terms as may be reasonably acceptable to that city, rather than in large measure to destroy the value of the Wachusett system.

Procedure Recommended by the Joint Board.

As previously stated in this report, the Joint Board proposed that the extension program embraced in the original report of 1895, eliminating the Assabet supply, be in general adhered to by building a new aqueduct from Wachusett Reservoir to the Ware River, which later should be extended to the Swift River, where an enormous reservoir should be constructed into which at some subsequent time the waters of the Millers, Deerfield and possibly other streams might be diverted in case the future demand for water warranted such action.

The plan for the development of these sources as recommended by the Joint Board, however, varies somewhat in detail from that originally suggested when the Wachusett supply was adopted. Because of the great industrial development which has taken place during the past thirty years in this section of the State, the waters of the Ware and Swift rivers are now fully utilized for the production of power and various manufacturing processes, and their diversion for domestic use would work irreparable injury to a great and important section of the Commonwealth. Instead, therefore, of taking the entire flow of these streams, the Joint Board proposed to divert for water-supply purposes the flood flows only, which otherwise would be wasted because they were in excess of the requirements and facilities of the industrial users along the course of the rivers below the point of taking.

As a consequence of this change of plan, it was no longer desirable or necessary to build a reservoir upon the Ware River, but the flood flows as they occurred could be diverted directly into the proposed aqueduct and be delivered for storage either into the Wachusett Reservoir or into the reservoir to be provided in the valley of the Swift River. The latter reservoir would be of such capacity that whenever it became desirable to do so the flood waters of other streams situated at higher levels could likewise be diverted into it to be held until needed to fill the reservoirs lower down in the system.

Meantime the normal flow in all of the streams would continue undisturbed so that their use for industrial purposes would not be interfered with. In fact, their value for such purposes might even be enhanced, since the flow could be controlled at the outlet from the main reservoir so as to deliver water to the industries below the dams in such volume and at such times as might be most advantageous.

Advantages of the Joint Board Plan.

There can be no question that from an engineering standpoint this proposal offers an excellent solution for the water-supply needs of the eastern portion of the State. From considerations of both quantity and quality this supply would be unexcelled by any substitute suggestion which can be offered. The water could be used without filtration, would flow to the district by gravity, and would entail no serious maintenance expense. The area flooded by the proposed reservoir is very sparsely inhabited, so that a minimum of hardship or inconvenience would be occasioned to present occupants. The cost *per million gallons* for developing this supply would probably be as low as that of any other possible alternative proposed, although since only a small fraction of the capacity would be required for many years to come there would be an idle investment during this period of a considerable amount. The taking of the water in the manner proposed would not be likely to damage any existing or prospective user of water below the point of diversion. The recommendation of the Joint Board, therefore, has much to commend it. Furthermore, if the assumptions made by the engineer for the Joint Board with respect to future consumption in the Metropolitan District should prove to be substantially correct, it is unlikely that any better source can be found that will meet the requirements as satisfactorily as will this one.

Objections to the Joint Board Plan.

The objections which have been raised against the proposed plan of the Joint Board are: first, that the taking of these important resources and the establishment of jurisdiction over such substantial areas by the people of a remote section of the State is repugnant to the desires of the several local communities that would be directly or indirectly affected, unless it

can be established beyond question that there is no other possible alternative solution of the water problem of the people in the eastern part of the State; second, the proposed plan appears to be unfair to the city of Worcester inasmuch as that municipality would be compelled to pump all of its future additional supply, elevating it several hundred feet either from a deep shaft on the aqueduct leading from the Ware River, or otherwise to take it from the Wachusett Reservoir. Also, judging from the previous attitude of the city of Worcester, it would be opposed to becoming technically or permanently a dependent of the Metropolitan Water District, subject to such rules and restrictions with respect to its supply as might be imposed upon it by the directing officials of that agency, and finally the great initial cost of the project would impose a serious financial burden upon the water takers of the district long before the debt for the original works is disposed of, thus pyramiding the expense for capital charges which at the present time constitute 70 per cent. of the total annual assessment levied upon the water takers of the District.

With reference to the first objection it may be said that opposition of this character is naturally to be expected under all similar circumstances, and it is undoubtedly based upon perfectly valid grounds. It cannot be honestly contended that the taking of the water of the Ware and Swift rivers as proposed in the Joint Committee's report is the only solution of the problem available at this time, even though in some respects it may be the best one. The interests of the several communities adjacent to the Connecticut River Valley are of such importance as to entitle them to the greatest consideration by the State at large. It seems extremely likely that the time may ultimately come when there is no other practical alternative by which a sufficient supply of water for domestic purposes can be obtained for the large metropolitan population in the eastern portion of the Commonwealth, and when that time arrives the wishes of the citizens of these local communities will necessarily be compelled to yield to this paramount consideration.

Similarly, the objections expressed in behalf of the city of Worcester are of compelling importance. It has been pointed out heretofore, that the future rights of that city to secure its additional water needs from the Wachusett watershed were apparently properly conserved in the Metropolitan Water Act of 1895. It is clearly evident to us that it is now highly undesirable that the proposed encroachment upon the Wachusett area should be permitted if other satisfactory arrangements can be effected. In view of these circumstances, we are of the opinion that the reasonable desires of the city of Worcester should be complied with in the selection of a substitute source, and that the Metropolitan District is not equitably in a position to dictate the terms of any contemplated compromise plan.

The third objection affects chiefly the people who are to use the new supply when it is developed. We have not deemed it necessary to check in minute detail the estimates of cost prepared by the engineer for the Joint

Board for constructing the works contemplated under its plan. Some rough computations made by our engineer would seem to indicate that the figures are reasonably close to those which might be expected to obtain at the present time. Experience with undertakings of this magnitude indicates, however, the probability that many modifications in design would inevitably result during the actual prosecution of the construction work involved, and that the final cost might therefore vary considerably from the preliminary estimates. Generally speaking, completion costs in such cases have proved to be greater than those originally anticipated. We have no reason, however, for believing that such a result would necessarily eventuate in this particular instance, and we are disposed for the purpose of this report to accept the estimated cost of the project as submitted by the engineer for the Joint Board as at least approximately correct.

Financial Effect of Adopting the Joint Board's Plan.

The present financial policy of the State is opposed to long-time maturities for loans made for public improvements because of the excessive cost of interest charges which accumulate over the period of indebtedness. A striking illustration of the burden imposed as a consequence of those deferred payments is disclosed by an examination of the record of experience with relation to the debt contracted in connection with the present metropolitan water system.

Prior to the year 1910, all construction loans for this purpose were floated in the form of sinking fund bonds running in each instance for a period of forty years or thereabouts. Subsequent to the year 1910, all bonds issued in connection with the undertaking have been of the serial variety, requiring yearly payments upon principal in addition to the annual interest charges. Up to January 1, 1925, there had been issued a total of $44 547 000 in bonds, of which $41 398 000 were in the form of sinking fund bonds, and $3 149 000 were of the serial form. Since a total of $422 000 has been paid upon the serial bonds prior to the present year, the net outstanding indebtedness on January 1 of this year was $44 125 000. Against this debt as an offset there is an existing sinking fund which has accumulated over the period and which amounted at the beginning of the present year to the sum of $21 396 342.90. If it were possible to apply this fund to the extinguishment of an equal portion of the debt, the latter would be reduced thereby to $22 728 657.10, but since the earliest date of maturity for any of these bonds is 1935, interest on the full amount must be paid each year until that date. Approximately one-half of the total sinking fund bond indebtedness will be extinguished by the year 1940, the major portion by 1945, and a small remainder by 1950, or twenty-five years hence.

It is of interest to note that during the entire life of the present works, up to January 1, 1925, there has been paid by the several members of the Metropolitan Water District a total of $55 290 087.37 as the aggregate of the several consecutive annual assessments representing the total net cost

of operation, plus charges of every description. Of this sum $11 548 532.31, or 20.9 per cent., represents maintenance and operation expense for the entire period; $8 785 937.58, or 15.9 per cent., was contributed to the sinking fund; and $34 955 618.48, or 63.2 per cent., was required to meet interest obligations on account of the debt. In other words, the average dollar paid to the State during the past thirty years by the member cities and towns of the Metropolitan Water District on account of water furnished to them, has been divided approximately 21 cents for direct expense of operation, 16 cents for extinguishment of the debt, and 63 cents to pay interest upon the debt. By the time the entire present indebtedness is finally retired, there will have been paid a total in interest charges of close to $57 000 000 upon a principal sum of only $44 547 000.

The existing law requires that any new funding operations must be carried out under the serial bond plan, which of course reduces the interest charges progressively as yearly payments are made upon the principal debt. Nevertheless, even under such an arrangement if the loan is negotiated upon a 4 per cent. basis, the total amount paid out in the form of interest will be as follows for various periods of maturity:

1 to 5 years total interest charges equal 12 per cent. of debt.
1 to 10 years total interest charges equal 22 per cent. of debt.
1 to 15 years total interest charges equal 32 per cent. of debt.
1 to 20 years total interest charges equal 42 per cent. of debt.
1 to 25 years total interest charges equal 52 per cent. of debt.
1 to 30 years total interest charges equal 62 per cent. of debt.
1 to 35 years total interest charges equal 72 per cent. of debt.
1 to 40 years total interest charges equal 82 per cent. of debt.

If, therefore, the Joint Board's plan was adopted and financed upon a forty-year serial bond basis, the final aggregate cost to the district would be $109 200 000, with the forty yearly payments grading downward from $3 900 000 to $1 560 000, whereas with a twenty-year period for extinguishing the debt the ultimate cost would be only $82 200 000, but the twenty yearly payments would vary from $5 400 000 down to $3 120 000.

The yearly payments referred to above, however, are based upon the assumption that the entire debt would be contracted at one time, which of course would not be the case. The estimated period required for construction is fourteen years, and it is presumed that successive issues of bonds would be negotiated over this term of years, with the result that a small part of the earlier loans would be retired on the serial basis before the final issue was operative.

It is true, as pointed out in an appendix to the Joint Board's report, that the surplus water revenues now accruing to the several cities and towns of the Metropolitan Water District growing out of their operations are in the aggregate of an amount sufficient to meet a substantial part of the increased cost such as might be imposed upon them if the proposed new supply were to be developed. On the other hand, this surplus is now available

either as a means of reducing water rates to the consumers or otherwise in meeting the cost of operations in some other departments of municipal government. If it were to be utilized for this new purpose it could no longer be applied to its present uses, with the result that other revenues would have to be found of a substitute character; and in any event the taxpayer would be required to meet the additional charge at one time or another.

There is another element in the financial situation which materially affects the problem under discussion. During the past fourteen years there have been only three in which bond issues have not been resorted to for meeting the cost of new construction of a miscellaneous character. For the period in question, these loans have averaged $225 000 per year, and they have varied from $34 000 to $1 000 000. There is every indication that these constant demands for year-to-year expenditures will continue during the remaining life of the works.

Of the $3 149 000 in serial bonds which have been issued during the past fourteen years, only $422 000, or 13 per cent., have been retired. These bonds have been issued upon a twenty to forty-year basis so that the debt for these purposes is increasing much more rapidly than it is being retired. Because of this fact it has recently been found necessary to provide for a direct annual levy, to be added to the other charges making up the yearly assessment, of $250 000 for a period of the next three years, and this practice will undoubtedly have to be continued so long as similar miscellaneous expenditures are found necessary, thus entailing an increase of approximately 10 per cent. in the charges for metropolitan water, regardless of the burden imposed by the proposed extension cost.

As previously stated in this report, immediate steps must be taken to provide filtration for the waters of the South Sudbury system, and while this commission is not called upon to study that particular phase of the problem, since the Metropolitan District Commission has the matter in hand, it seems probable that whatever plan is recommended for accomplishing the purpose, it is likely to involve an immediate expenditure of upwards of $3 500 000 and ultimately of $5 000 000, which must be reckoned as another factor affecting the future cost of water to the metropolitan takers, not only increasing the yearly contribution from which to meet capital charges, but as adding something to the cost of operation as well.

Alternative Plan Preferred.

In view of the adverse considerations mentioned we are of the opinion that the recommendations of the Joint Board, involving, as they do, such serious increased financial burdens upon the water takers of the district, are of doubtful widsom. In reaching this decision the members of this Commission have not been unmindful of the distinguished character of the personnel of the Joint Board itself nor of the high professional standing, experience and qualifications of its engineer, Mr. X. H. Goodnough, and

its consulting engineer, Mr. J. Waldo Smith, both of whom are generally recognized as competent authorities upon the subject of water supply. It is because the otherwise excellent solution offered by them for the water problems of the eastern section of the State conflicts with what seem to us to be rather controlling requirements in the case, that we have felt constrained to seek an alternative suggestion which will assure relief from danger of a water shortage in the Metropolitan District and at the same time avoid the objectionable features outlined.

Proposed Alternative Plan.

We are in accord with the views expressed in the report of the Joint Board with reference to the desirability of eliminating from consideration the possibility of developing new supplies from such sources as the Merrimack River, Charles River, Shawsheen River or the other watersheds heretofore frequently suggested but which are located outside of the State. There are, however, some available additions of substantial amounts which can be made to the present metropolitan water supply from comparatively near-by sources which will render it possible to defer encroachment upon territory in the western portions of the State for a considerable period.

The Assabet River as a Source of Supply.

The Assabet River watershed, located between those of the Sudbury and Nashua rivers, was considered in the original report of 1895, and was suggested therein as the possible next step in the future development of that system. The aqueduct which carries the Wachusett water to Sudbury Reservoir passes through the Assabet watershed and could be readily utilized for conveying water from this source to the delivery conduits of the system. Approximately one-half of the water which would be obtainable from this source could be made to flow into the aqueduct by gravity, and the remainder would require low-lift pumping.

The engineer of the original investigating board in 1895, estimated the usable capacity of this source as 28 mil. gal. per day. The engineer for the Joint Board placed the maximum daily capacity which could be safely taken from this source, at only 11 mil. gal. because of the necessity for maintaining a considerable flow in the river below the points of taking in order to supply large quantities of process water for industrial purposes and for certain sanitary requirements in the stream itself.

Our engineer, however, advises us that it will be possible to develop this source in such a manner as to obtain a dependable supply of 47 mil. gal. per day. Whereas it was originally planned to divert only that portion of the flow which would run by gravity into the Wachusett aqueduct, Mr. Hazen points out the possibility of securing a large additional amount of water by resorting to electrically driven low-lift pumps, which method would permit of utilizing a greatly increased area of the watershed.

In order to meet the necessity for supplying process water to the industries along the river, and also to conform to the requirements for water to maintain the sanitary condition of the river in a satisfactory state, Mr. Hazen proposes that a special reservoir be built on the river just above the town of Hudson, which could be used solely for the purpose of equalizing the flow in the stream, storing flood flows in periods of freshet, and releasing the waters thus held at times of low run-off. The particular portion of the flow which would supply this reservoir with its water would be mainly that part which is unsuitable in quality for water-supply purposes, and its use for the proposed compensating service therefore would not reduce in any degree the total volume of water available for increasing the metropolitan supply.

The estimated cost of developing and delivering to the present system this 47 mil. gal. per day of additional water, is $8 403 000, or $179 000 per mil. gal., which is an unusually low figure — probably much cheaper than any other available source of equal capacity. This cost is due to the fact that no very large reservoirs are involved in the contemplated construction, since the Wachusett and Sudbury reservoirs would be utilized for storing the water, and also to the fact that the aqueduct for delivering this supply to the system is already available.

This is undoubtedly the cheapest and most expeditious manner of securing a substantial addition to the present supply of water for the Metropolitan District.

Possible Early Need of General Filtration.

The introduction in considerable quantity of water from the Assabet River into the Sudbury Reservoir would, because of its high color, probably necessitate resort to immediate filtration of the entire supply, including the Wachusett, since all of these waters would mix together in their passage through that basin. However, the time is close at hand when the water from both the North Sudbury and Wachusett sources must be filtered if a safe standard of quality is to be maintained in the future.

There is already an undesirable number of sources of pollution present in the Wachusett watershed. The population upon the area is increasing rapidly, and industrial wastes are finding their way into the streams in constantly greater amounts. The long storage afforded by the great capacity of the Wachusett Reservoir serves to eliminate these impurities by natural processes so long as it remains reasonably full. As it becomes necessary to draw down the level of the reservoir to considerable depths, the period of storage is reduced to a corresponding degree with a lessening of its efficiency as a purifying agency.

In the case of the Sudbury Reservoir the situation is even more serious. The principal area of the city of Marlborough lies within its watershed, and the effects of pollution upon the waters of this basin have become so marked that serious thought has been given in recent years to a proposal for building

a by-pass tunnel around Subdury Reservoir to permit the delivery of Wachusett water directly into the Weston aqueduct, thus avoiding the possibility of its pollution in its passage through that basin.

There is another important consideration which tends to make filtration desirable. As pointed out in our engineer's report, in the absence of filtration, purification of the water must be secured by long storage in reservoirs. If it becomes necessary to draw from storage excessively, as is now being done at the Wachusett Reservoir, the diminished volume may not afford an opportunity for holding the incoming raw water for a sufficient period in which to assure the complete sterilization and bleaching which is required to produce a satisfactory quality for domestic consumption. If, on the contrary, the water is subsequently filtered after passing through the reservoir, the initial storage purification need not be depended upon, and such a reservoir may be drawn to the very bottom, if necessary, with no harmful effect.

The depth to which a given reservoir may be safely drawn is an important factor in determining the dependable yield of that particular source, so that filtration serves to increase materially the available capacity of the supply. In other words, the filtration of the present Wachusett supply would increase the amount of water obtainable from it, and in the opinion of our engineer if the Wachusett supply were to be filtered, the supply of water obtained from that source would be increased 8 mil. gal. per day.

Filtration works suitable for the Wachusett, Assabet and North Sudbury waters, will cost at present prices approximately $10 500 000. There will also be added an operating charge of perhaps from two to three dollars per mil. gal. Furthermore, complete filtration of the entire supply will make necessary the elimination of all open distributing reservoirs and the substitution of covered reservoirs, since filtered water cannot be stored in the open without rapid deterioration due to the growth of organisms.

Possible New Sources of Supply for Worcester.

If the proposed Swift River supply is excepted, there are only two possible independent sources other than the Quinapoxet River available to that city from which to augment its present deficient supply.

A considerable development is possible by utilizing Stiles Reservoir, so called, lying to the west of the city, which supply could later be enlarged by pumping from Five-Mile River (Lake Lashaway), making possible a total ultimate supply of 25 mil. gal. per day. This supply would be comparatively expensive to develop, the greater portion of the water would require pumping against a 300-foot lift, and the power damages for such a taking would be extremely heavy with no opportunity for compensating the established industries, which would be affected, with substitute water.

The alternative supply is that to be obtained from the high lands tributary to the upper Ware River at Barre Falls. The possibility of developing a high level supply at this point was first suggested some few

years ago by Mr. William E. Foss, director and chief engineer of water supply for the Metropolitan District Commission. A reservoir constructed at this site will permit of a gravity flow to some of the existing Worcester reservoirs and to the Wachusett Reservoir.

Such a development is capable of producing a supply of 45 mil. gal. per day, sufficient to care for Worcester's additional water needs for a great many years in the future. The site of the proposed reservoir has been thoroughly surveyed by our engineer, dam locations have been explored by means of test borings, and sufficient information has been obtained to determine the entire practicability of utilizing this source. Considering the large amount of water obtainable, the fact that it will flow by gravity to the Worcester system, the quality of the water, and the reasonable cost of developing the works, this solution is undoubtedly far superior to any other plan yet proposed.

Compensating Reservoir for Power Users.

The diversion of such a substantial amount of water from the normal flow in the river below the dam will necessarily affect adversely the several industrial users of water along the Ware and Chicopee rivers. Because of the intensive use of this water for manufacturing and power purposes a careful study has been made by us in order to devise some possible method of compensating these industries with an equivalent substitute. It will be feasible to construct an independent compensating reservoir on the upper portion of the river of sufficient capacity, by damming the stream at a point near the village of Coldbrook, creating a storage basin which will retain the flood flows, making the water thus stored available to the mills during the months of low flow in such amounts as may be required. By such a means full compensation can be made in kind for the water which would be diverted for water-supply purposes from the upper reservoir above Barre Falls. The cost of this compensating reservoir will be considerable, approximately $4 000 000, but the damage which would otherwise be suffered by several of the State's important industrial enterprises seems fully to justify the expenditure. Negotiations have been had with representatives of the several interests which would be affected, and there is substantial unanimity among them that such a solution for maintaining the dry-weather flow of the river would be entirely satisfactory and would be accepted by them in lieu of money damages.

The estimated cost of developing this supply of 45 mil. gal. per day, including payment of water damages or the aforesaid compensating reservoir, together with the works for storing the water and delivering it to the Metropolitan or Worcester supply, is approximately $14 000 000, the details of this figure appearing in the accompanying report of our engineer.

Division of Cost of Proposed North Ware Supply.

There is substantial agreement among all of the engineering authorities who have investigated the subject that the cost to the city of Worcester

of developing a supply on the Quinapoxet River would be in the vicinity of $1 800 000, including reimbursement to the Metropolitan District for the water taken in accordance with the provisions of chapter 456, Acts of 1897. For this expenditure the city might secure a total additional supply equal to about one-fourth of the capacity of that obtainable from the North Ware. This increase in the city's water supply would very likely meet its requirements for a further period of twenty to twenty-five years. This water also would all require pumping to one or more of the city's present reservoirs in order to make it available. The capitalized cost of this pumping would probably add about $750 000 to the cost of the Quinapoxet supply, for the purpose of comparison with a gravity source such as the North Ware, making the total cost of this development about $2 550 000.

It would be obviously inequitable to require the city of Worcester to make a present investment of $14 000 000 in a supply which would be considerably in excess of its needs for many years to come, in view of the fact that a much smaller investment in the Quinapoxet project would answer its purposes for a considerable period. It is our conviction that the Metropolitan District should join with the city of Worcester in developing the North Ware supply, assuming the major portion of the financial burden and utilizing the surplus capacity over and above the requirements of Worcester as an addition to its present supply by permitting it to flow by gravity into Wachusett Reservoir. The entire quantity of water available from this source should be definitely dedicated to the ultimate future needs of the city of Worcester, but that municipality should not be required to take the supply or to pay for it except as it is needed to meet the requirements of Worcester's growth. In the meanwhile, there will be a very valuable surplus which can be used by the Metropolitan District and thus defer the date when it must make heavy expenditures for an additional source.

It is assumed that in the beginning Worcester will not take more than 5 mil. gal. per day, or one-ninth of the total capacity. We propose, therefore, that the city shall be required to pay one-ninth of the cost of development expense, and to contribute one-ninth of the annual cost of maintaining and protecting the works, the balance to be paid for and used by the Metropolitan District. Whenever from time to time in the future the city of Worcester requires additional water, it should have the right to serve notice upon the Metropolitan District of its intention to take an increased proportion of the North Ware supply in successive increments of 5 mil. gal. per day by paying into the State treasury for the account of the Metropolitan Water District, one-ninth of the cost of the entire development for each 5 mil. gal. per day so taken. Thereafter the city should be required to contribute to the expense of the operation and upkeep of the supply in direct proportion to its total water-taking therefrom.

It may be urged that under the method herein outlined for reimbursement of principal, only by the city of Worcester, the entire interest requirement will be borne solely by the Metropolitan District pending the taking

of the city of additional quantities. We think this involves no element of injustice inasmuch as the District must in any event develop a new source of supply for its own requirements upon the cost of which it will be required to pay interest charges. If, therefore, it is permitted to defer this new construction for its own account by using and paying for the surplus supply from the North Ware, it suffers no financial loss by so doing. Furthermore, even under these terms the city of Worcester will be called upon to pay a substantially larger sum for the initial addition to its supply from this source than would have been required had it been permitted to take the same amount of water from the Quinapoxet River as it has previously sought to do. We believe this arrangement is an equitable one for both parties, regardless of any rights which Worcester has to the Quinapoxet supply.

Advantage of Joint Use of North Ware Supply.

The dual use of this supply by the city of Worcester and the Metropolitan District provides for a most efficient utilization of the development. Instead of permitting the major portion of the investment to remain idle for a long period of years, as is usually unavoidable in the case of new water supplies, this one would supply service to the extent of a very considerable portion of its capacity almost from the beginning.

In view of the fact that the immediate development of this supply seems necessary in order to provide adequately for the city of Worcester, and since upon its completion there will remain an unused surplus of 40 mil. gal. per day which will diminish by successive increments as Worcester's needs demand an increasing proportion of the total capacity of the source, the use by the Metropolitan District of this excess will defer for several years the utilization of the Assabet supply previously referred to.

Date When Assabet Supply may be Required.

According to our estimates of future consumption requirements, the 45 mil. gal. per day obtained from the proposed North Ware source, added to the combined total of existing supplies, will provide water for the future needs of all the communities to be served until the year 1941. Therefore, by the year 1937, or thereabouts, it will be necessary to commence operations looking to the utilization of the Assabet supply in order that it shall be available for use when required.

After adding the 47 mil. gal. per day capable of being obtained from the Assabet source, the total supply will be increased to 298 mil. gal. per day, or an amount sufficient to meet requirements, according to our figures, until the year 1954, or twenty-nine years hence. Before that date a third source of supply must be selected and developed.

Ipswich River as a Source of Supply.

A satisfactory near-by source for this purpose is available in the watershed of the Ipswich River, above the town of Topsfield, at which place a

convenient location exists for a dam about 25 ft. in height, which would create a reservoir with an area of 6 600 acres. The watershed which would contribute to this supply would be approximately 118 sq. miles, practically identical with that of the Wachusett before a small portion was transferred to the city of Worcester. The reservoir would be of considerably less depth, however, than that of the Wachusett, and would provide storage for only about one-half the quantity of water. Our engineer estimates that this development would be capable of supplying 80 mil. gal. of water per day.

Approximately three-eighths of the capacity of this source, or 30 mil. gal., will ultimately be required for the water needs of the surrounding cities and towns which must look to this source in the future for extensions of their present supplies. The balance, or 50 mil. gal. per day, and more during the earlier years of its operation, could be made available for use by the Metropolitan District. It constitutes a future resource for water-supply purposes which should not be ignored in our present considerations, and it is recommended that the development of this supply be adopted as the third contemplated stage in the progressive increase that is likely to be required for supplying the future water needs of the district.

This supply lies in a northerly direction from the Metropolitan District, and there would be a distinct advantage in receiving such an amount of water at or in the vicinity or Spot Pond. The latter reservoir is now at the remote end of the distributing system. As consumption increases between the point of entry of the water into the system and this point, it becomes more difficult to maintain the delivery of water under adequate pressure to all parts of the District. This result can be secured, of course, by increasing the size of the several main pipe lines, but the same effect would be obtained by feeding an additional supply such as that to be obtained from the Ipswich into this end of the pipe system. The saving effected by this means would be considerable and could be used as an offset in part against the cost of developing the proposed supply.

The proposed development would also practically settle the water-supply problems of all of the cities and towns of the surrounding territory, many of which, particularly Salem, Beverly and Peabody, are already in need of some assistance of this nature.

The precise dates involved in carrying out the contemplated plan of successive stages of development will vary in accordance with a variety of influences at present unknown and undeterminable. If the actual future growth proves to be more rapid than we have assumed, the several dates used herein will be correspondingly reduced and the total period of sufficiency will be shortened. On the other hand, if we have ourselves overestimated the rate of future growth, as has been done in the case of former forecasts, then it is obvious that all of the successive steps can be deferred to a still later date than that indicated by us.

In any event, it would appear to be futile to speculate at this time upon

the water requirements of such a remote period as forty years or more hence. Improvements in the art and other conditions which cannot now be foreseen will undoubtedly render any conclusions at this time worthless when that date arrives.

The precise selection of the most satisfactory additional supply for that period may well be left to the choice of the people then primarily interested, who, presumably, will be in a much more advantageous position to judge of the respective merits of the various proposals then open to them.

Possible Increase in Hobbs Brook Supply.

There is one other possible increase to the supply that may be obtained from a near-by source that we have seen fit to eliminate from our recommended program because it appeared to be less satisfactory than those so far discussed. Whether it will be equally available for development forty or fifty years hence may be open to doubt.

We refer to the possible further development of the Hobbs Brook supply of the city of Cambridge. By raising the dam of the present reservoir some 30 ft. in height, an enormous basin would be created into which the flood flows of the lower Sudbury River could be pumped, thus providing an additional capacity to the present source of some 30 mil. gal. per day.

Pumping from the river would need to be limited to periods of high flow, and pumps and pipe lines of large capacity would be required, operating at infrequent intervals. As in the case of the Assabet and Ipswich supplies, filtration would be required, although the long storage made possible by the enlarged reservoir would greatly improve the quality of the water.

The cost of developing this additional supply would be comparatively high, and operating expense would also be considerable. For these reasons, it has seemed to us desirable to drop it from consideration at this time. It may be, however, that the city of Cambridge will wish at some future date to avail itself of this opportunity to increase its own supply rather than to seek assistance from the Metropolitan source. In that event it will bring into the District, considered as a whole, an additional amount of water which will serve the purpose of extending the life of the Metropolitan supply which otherwise would be called upon to furnish all such deficiencies. It seems unlikely that this source will be available for many more years, since the growth of population and suburban development upon the area required both for reservoir and supply sites will before long make their taking prohibitive.

Deficiency of Present Distribution System.

So far our discussions have related principally to the subject of possible new sources of supply, and the report of the Joint Board related exclusively to that branch of the problem. It is well, however, that the water-takers of the district should be appraised respecting other requirements of the case that are bound in any event to add materially to the future cost of water in the District.

If the aqueduct leading from Lake Cochituate to Chestnut Hill Reservoir is eliminated along with the water from that source, as it would be and should be, the entire supply is required to reach the distributing system either through the Sudbury or the Weston aqueducts. The former was the principal conduit for bringing the Boston water supply to that city prior to the development of the Metropolitan system, and was taken over with the works in 1898 by the District. It is capable of delivering 100 mil. gal. per day, and in the early years of the Metropolitan service the entire supply was carried by this aqueduct to Chestnut Hill, where it was pumped to the several communities served.

When this aqueduct was no longer sufficient to handle the water used, a new high-level aqueduct, known as the Weston Aqueduct, was constructed, leading from the dam of Sudbury Reservoir to a terminal chamber at Weston, where the water is delivered at an elevation of approximately 200 ft. above sea level, or 65 ft. higher than Chestnut Hill Reservoir.

This aqueduct has in the main a capacity of 300 mil. gal. per day as far as this terminal chamber. There are, however, two syphons in the line of the aqueduct in each of which three steel pressure pipes were designed to carry the water across natural depressions. Only one of the three steel pipe syphons has so far been installed, so that for the two syphon sections in question, the aqueduct has only one-third of its designed capacity, and additional syphon pipes are now required to provide for the increasing draft through this conduit.

The terminal chamber at Weston is some 11 miles west from Boston Common and somewhat over 8 miles from Chestnut Hill Reservoir. The only connections at the present time between the terminal chamber and the distributing system consist of one 48-in. and one 60-in. line of cast-iron pipe, both of which deliver to the pumping station at Chestnut Hill. The combined capacity of these two lines is probably not much in excess of 50 mil. gal. per day, or one-sixth of the full capacity of the Weston Aqueduct. There is now approaching completion of a new 60-in. steel pipe line with an approximate capacity of 40 mil. gal. per day, which will deliver water direct from the Western terminal to the heart of the district so that the combined capacity of all available lines will soon become 90 mil. gal. per day. The peak demand for water, however, is far above this amount at certain times of day, and is apt to be at least 50 per cent. in excess of the average draft, especially at times of conflagration and the like, so that this figure should not be compared with the estimates of daily consumption demand previously referred to.

Furthermore, in the case of iron or steel pipes there is a continual diminution in capacity due to accumulations of deposits on the interior surface which not only reduce the cross section of the pipe, but also add materially to friction, thus lessening the velocity of flow. On this account alone, the total capacity of these three lines to deliver water may be expected to be reduced at the rate of perhaps 5 mil. gal. in each decade.

Upon this basis it will be seen that the existing connections are adequate to care for an average demand from the District of only 60 mil. gal. per day from the Weston Aqueduct, which, if added to the capacity of the present Sudbury Aqueduct, will be safe for but little more than the present total consumption requirements of the District, with a constant future reduction as the steel and iron pipes deteriorate.

The present average water consumption of the District is about 130 mil. gal. per day, so that all future increases must be cared for by the Weston Aqueduct and its connections. This will involve the construction of a new 6-ft. steel pipe line, approximately every ten years at an expenditure of from $2 000 000 to $3 000 000, or from $200 000 to $300 000 per year as a continuous program.

As an alternative, we have had studies made of the comparative cost of a deep pressure tunnel in the rock which would in effect extend the Weston Aqueduct into the heart of the District and render unnecessary this multiplicity of steel pipe lines.

Such a tunnel with a probable diameter of 11 or 12 ft. would serve greatly to increase the available water pressure in the District, and would eliminate the greater part of the pumping now required at a capitalized saving of perhaps one and three-quarters millions of dollars. At the present time about 75 per cent. of all the water used by the District requires pumping in order to maintain an adequate pressure.

There is also some question whether suitable locations in the several streets can be readily found for the ever-increasing number of pipe lines required. In addition there is an unavoidable disturbance and damage of serious proportions involved to the several communities through which these lines are laid during the process of installation. The tunnel, on the other hand, would be located several hundred feet below ground in the underlying ledge, with only occasional shafts reaching the surface at convenient points for connection with the existing street mains.

Another factor of possible major importance involved in the question, is the protection afforded against interruption to the supply in the event of a destructive earthquake. Experience has shown that the principal damage occasioned in the past by earthquake, has been that caused by fire following the breakage of the water-supply conduits. In order to reach their destination, the several steel pipe lines leading from the Weston terminal will have to pass through areas of filled and unstable land in which the effect of quakes is particularly severe.

In addition, however, to all of these considerations it appears from such studies as we have made of the subject, that the comparative cost of the two methods of distribution is decidedly in favor of the pressure tunnel, although its first cost looks rather impressive.

It is our judgment that this question is one of vital importance to the District, which should receive immediate attention. It may be that some further study of the matter, with especial reference to the precise location

of a tunnel line, including proper exploration by test borings and the like, is desirable before definitely adopting a program, but decision upon the question cannot be long postponed.

Financial Program Involved with an Increased Supply.

It is apparent that the Metropolitan Water District is confronted with the necessity of paying considerably more for its water for the next twenty to thirty years than it has paid in the past. There is nothing to be gained by attempting to disguise this fact. Our engineer has indicated in his report the progressive program of development which is required to meet the needs of the Metropolitan District and Worcester, including the necessary expenditures for securing additional water and of distributing it to the consumers.

This suggested procedure calls for an outlay during the ensuing ten years of $47 500 000, and embraces the development of the North Ware supply, initial installation for South Sudbury filtration, completion of syphons on Weston Aqueduct, pressure tunnel from Weston terminal to center of District, miscellaneous construction items of a recurring nature, and purchase of land and rights in connection with proposed future Assabet and Ipswich supplies.

For the succeeding decade there will be required a further expenditure of about $24 000 000 for completion of the Assabet supply, filtration of Wachusett, Ware and Assabet waters, changes in reservoirs on account of filtration, building reservoir on Ipswich supply and customary miscellaneous improvements.

During the third ten-year period, there will be needed $14 000 000 for completing the program, including Ipswich filters and pipe line, additional Sudbury filters, and minor yearly enlargements to existing works.

The total expenditures called for during this thirty-year period is seen, therefore, to be $85 500 000, which sum will be reduced to the extent of such reimbursement as the city of Worcester may make on account of increasing its taking from the Ware supply.

Of this amount $31 500 000 is involved in the development of new sources of supply aggregating a total increase to present capacity of 180 mil. gal. per day; $5 000 000 will be necessary under any plan for filtering the South Sudbury supply which will make available 26 mil. gal. per day not now used; $24 000 000 will represent the cost of filtration, made necessary by the use of higher colored waters subject to possible pollution; and will increase the supply obtainable from Wachusett Reservoir 8 mil. gal. per day by permitting the drawing of larger amounts of the stored water. This figure also provides for the cost of covered distributing reservoirs and other necessary changes in the system. Twenty-five million dollars is the approximate sum required to bring the increased quantity of water into the District and to care for year-to-year construction requirements.

Assuming the estimate of the Joint Board of $60 000 000 for the development of the Swift River supply to be approximately correct, there should be added for the purpose of comparison with our own expenditure program $5 000 000 for the Sudbury filters, $8 000 000 for avoiding filtration of the main supply by the purchase of sufficient land, industries and other property to protect the quality of Wachusett water, and also by constructing an independent connection for delivering Wachusett and Swift water directly to the Weston Aqueduct without mixing with that of Sudbury Reservoir, and $25 000 000 for distribution needs, making a total expenditure of $98 000 000 spread over a period of fourteen years in place of the $85 500 000 contemplated above, distributed over a period of thirty years and possibly longer, depending upon the rate of future growth of population.

In case the municipalities adjacent to the Ipswich supply were to avail themselves of the 30 mil. gal. per day which has been allocated to them under our plan, the total expenditure by the Metropolitan District would be reduced, perhaps, by as much as seven or eight million dollars, but the quantity of water available to the District would be lessened by that amount.

The cost *per million gallons* of water secured under either of these plans would be substantially the same, or about $490 000. The completely filtered supply would provide a better and safer water, and the plan could be developed piecemeal. The advantage, therefore, would seem to lie with that selection.

Against this initial advantage there must be offset the operating cost of filtration and of the pumping of the Ipswich supply, which cost would not be required in the case of the Swift supply and which might reach a total of perhaps $500 000 per year by the time the total capacity of these sources is reached. The sum if capitalized would represent a principal sum at that time of approximately $12 000 000. During the early periods of use of filtration the costs would of course be correspondingly less.

The accompanying chart has been prepared for the purpose of showing the probable fluctuation in the yearly cost per million gallons to the water-takers of the District under each plan. It has been assumed that a direct levy will be made each year of $250 000 from which to finance all miscellaneous construction requirements, and that the balance of the cost will be refunded upon a thirty-year serial basis at 4 per cent. Superimposing all of the burden of new financing upon the existing requirements, including estimated increases in cost of operation, produces the results as shown.

It will be seen that the present cost per million gallons of water delivered to the member municipalities, will rise under our plan to a maximum of $102.50 by the year 1939, and that under the proposal of the Joint Board, a figure of $120 would be reached by the year 1931. Subsequently there will be a gradual reduction, bringing the cost back to the present figure by the year 1956.

The maximum figure reached would represent, if reduced to the consumer's unit, the sum of 7.7 cents per 100 cu. ft. on the one hand, and 9 cents on the other. Looked at from this angle the increased cost of water is not excessive, since, if there be added to this figure the cost of local administration and distribution of, say, 5 cents, the resulting cost for all expenses of every description would be only 12.7 cents and 14 cents, respectively.

It is the practice of the Metropolitan District Commission, to charge the member municipalities of the Metropolitan Water District each year

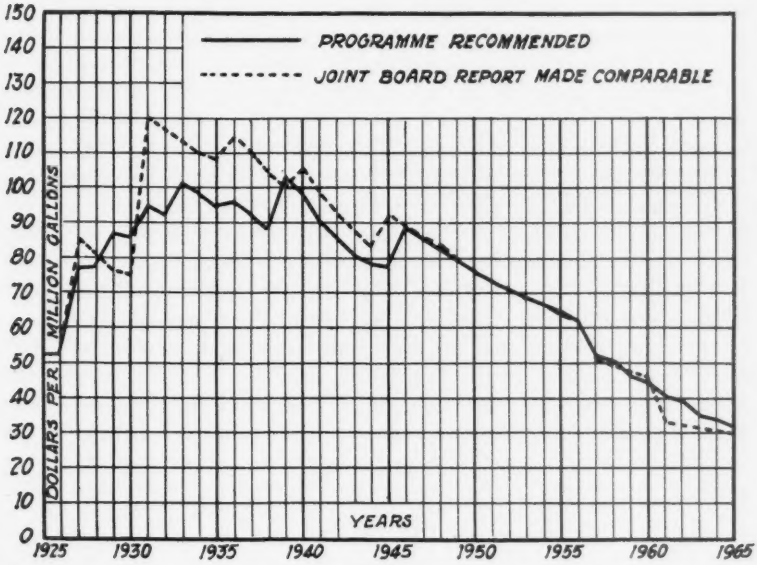


FIG. 1.

the actual cost of operations, including all charges of both a direct and indirect nature.

The cities and towns using this water, however, are accustomed to charge the individual consumer upon the basis of an established rate for the water used, irrespective of its actual cost, with the result that in the ordinary year there remains a substantial surplus to the municipalities, considered as a whole, of water revenues over and above the combined expense of metropolitan and local costs.

In those cities and towns where such a surplus accumulates it is the practice to apply this profit to other municipal purposes in whole or in part, and thus the water consumer contributes not only the actual cost of securing and delivering his water supply, but frequently is called upon to pay by this indirect method for improvements and activities which normally would be provided for out of the general tax levy.

If the program now proposed by us is carried out, and if the ultimate consumer is made to pay the entire additional costs which will result, it will probably be necessary to raise water rates in the Metropolitan District for the next thirty years by approximately 25 per cent. over the present figure, whereas if the program recommended by the Joint Board were to be adopted, this figure would be approximately 30 per cent.

If, on the other hand, the various rates were adjusted so as to cover only the exact cost of producing and distributing the water to consumers, the increase in rates under our plan would probably not exceed 7 per cent., and under that of the Joint Board, 12 per cent.

The difference in cost between the two plans may not appear to be impressive when measured in cost per million gallons, since the excess cost of the Joint Board plan over that now proposed, averages only $6 per million gallons for the next thirty years. The total saving represented during this period, however, is approximately $12 500 000, of which $11 000 000 applies to the first twenty years, so that the saving to the communities affected will be very substantial. In addition to this fact the community will be supplied under the program now proposed with filtered water of the highest degree of purity as compared with natural waters, which, however excellent their quality may be, are always subject to the possibility of accidental pollution and at times to tastes and odors of an objectionable nature.

It is our opinion that an immediate appropriation of $27 500 000 should be authorized by the Legislature, and that a special commission should be created to construct the South Sudbury filters; to develop the North Ware supply; to make necessary land and property taking upon the Assabet and Ipswich watersheds for future needs; to make further studies and report to the next Legislature upon the subject of a pressure tunnel; and to secure a suitable site for a filtration plant along the Weston Aqueduct.

Conclusions.

As a result of a study extending over more than a year, we are convinced that the Metropolitan District is confronted with a critical situation respecting its water supply, both from the standpoint of capacity and of distribution facilities.

The system is underdeveloped for the service it must supply in the very near future. In our opinion immediate action is necessary in order to avoid the possibility of consequences of a serious nature. Undoubtedly the restrictions imposed by the war period and the subsequent high costs of construction have been largely responsible for the failure to keep pace with growing requirements, but further postponement will be extremely dangerous.

In periods of sufficient rainfall, it is difficult for communities to realize the possible consequences of a recurring dry spell such as is to be expected at intervals of from fifteen to twenty years. The last period of severe drought occurred about fifteen years ago. It is reasonable to anticipate

another within the next few years. The time to prepare for such an emergency is before its occurrence. To wait until the crisis is here will be futile, since there will not then be sufficient time available in which to provide the necessary remedial measures.

It may be urged that there is now sufficient water obtainable with which to meet such an emergency if quality is disregarded, and this may be true to a certain extent. Its use, however, in an unpurified state will be fraught with danger to the health of the community unless chemical treatment is resorted to, in which case it is likely to prove decidedly unpleasant as a beverage and quite unacceptable to a population that has become accustomed to a high standard of quality in its water supply.

The distribution system, particularly that portion pertaining to the delivery pipes from the Weston Aqueduct, has been permitted to lag behind the actual requirements for capacity, so that it is only by an ingenious manipulation of the pumping equipment that sufficient pressure is maintained at all times in the system. This constitutes a serious hazard in case of any exceptional demand for water, such as a serious conflagration, or severe cold spell. Likewise, the crippling of one of the pumps or the breaking of a force main would be likely to result disastrously. In our opinion this feature also should have immediate attention and correction, and the system should be brought at once to a state where maximum and emergency requirements can be met with a reasonable margin of safety.

ACKNOWLEDGMENTS.

We desire at this time to record our sincere appreciation of the uniform courtesy and coöperation which has been accorded to us throughout the period of our investigation, by the State Department of Health and its chief engineer, Mr. X. Henry Goodnough, and by the Metropolitan District Commission and its director and chief engineer of water supply, Mr. William E. Foss. It is a distinct pleasure for us to testify to the cordial and sympathetic interest which these parties, together with their respective staffs, have manifested toward our work, and their assistance has been invaluable.

It is our judgment that the cost of this investigation and report should be divided between the Metropolitan Water District and the city of Worcester, seven-eighths to the former and one-eighth to the latter.

In accordance with a provision contained in the act creating this Commission, we are submitting herewith a suggested draft of legislation for carrying out the recommendations of this report.

Respectfully submitted,

CHARLES R. GOW,
GEORGE F. BOOTH,
ELBERT E. LOCHRIDGE,
Metropolitan Water Supply Investigating Commission.

DECEMBER 1, 1925.

INFORMAL PROGRESS REPORT OF THE COMMITTEE ON STANDARDIZATION OF SPECIFICATIONS FOR CAST-IRON PIPE.

BY FRANK A. McINNES.

As you all know, a joint committee of the American Water Works Association and this Association has been engaged on this subject for more years than I care to mention. The incentive has always been from the Committee, never from the manufacturers. We have made definite progress, but have not achieved the desired result; and now the joint committee has been superseded by an agency nation-wide, yes, international in its scope, which presumably should prove more effective in getting the desired results in a reasonable length of time. I will try to tell you the history of this new organization. It began when the American Gas Association and the American Society for Testing Materials requested the American Engineering Standardization Committee to approve their respective existing specifications. I might say that the specifications of the American Society for Testing Materials is practically the same as that of the American Water Works Association.

The next step was taken by the American Engineering Standardization Committee in the appointment of a special committee of their own; which committee reported, or advised that a convention be held which would represent all interests chiefly interested in this subject. That convention was held in the city of New York in June, 1924. There were present some forty-seven persons representing thirty-six different organizations, and it was voted that the American Engineering Standardization Committee be requested to initiate standardization work on the subject of cast-iron pipe as one of its regular projects. The American Engineering Standardization Committee accepted this suggestion, and at once set its machinery at work.

Four sponsor bodies were appointed, namely, the American Gas Association, the American Society for Testing Materials, the American Water Works Association, and the New England Water Works Association; each of these sponsor bodies appointed one member who should be one of a Committee of four to form a Steering Committee of the Sponsors, whose duty it was to organize a sectional committee, whose duty in turn was to actually formulate the specifications. The Steering Committee of the Sponsors is C. L. Warwick, Chairman, representing the American Society for Testing Materials, C. W. Morris, representing the American Gas Association, F. A. Barbour, representing the American Water Works

Association, and F. A. McInnes representing the New England Water Works Association.

This Steering Committee held two meetings, both in New York City; the first in September, 1924, when the general scope of the proposition was discussed and outlined; the second and last in April, 1925, when the organization of a Sectional Committee to develop the new specifications was decided upon. Since that time the personnel of the Sectional Committee has been formulated. It consists of 31 members, 11 of whom are called Producers, that is, manufacturers of pipe; 15 are termed Consumers, and are those who use pipe, or are directly interested in the use of pipe; and 7 are termed General Interests.

The following is the organization in greater detail. First, the Consumers, consisting of three representatives of the American Gas Association, one representative of the American Railway Engineering Association, two representatives of the American Society of Mechanical Engineers, five representatives of the American Water Works Association, and three representatives of the New England Water Works Association. Next follows the General Interests, consisting of one representative of the American Society of Civil Engineers, three representatives of the American Society for Testing Materials, one representative of the National Fire Protection Association, one representative of the United States Bureau of Standards, and one representative of the Underwriters Laboratories.

Now we come to the Consumers with one representative of each of the following: the American Cast Iron Pipe Company, Birmingham, Ala.; J. B. Clow & Sons, Chicago; Donaldson Pipe & Foundry Company, Emaus, Pa.; Glamorgan Pipe & Foundry Company, Lynchburg, Pa.; the Lynchburg Foundry Company, Lynchburg, Va.; the National Cast Iron Pipe Company, Birmingham, Ala.; the Warren Foundry & Pipe Company, Phillipsburg, N. J.; R. D. Wood & Company, Philadelphia, and three representatives of the United States Cast Iron Pipe Foundry Company, Burlington, N. J.

It would seem that the interest of the Consumers is well safeguarded under this arrangement, of 11 producers, 14 consumers, and 7 general interests. A chairman has not yet been appointed for this committee, and of course no meeting has as yet been held. That is the present status of the matter as far as I know.

CEMENT-LINED CAST-IRON PIPE.

BY CHARLES W. SHERMAN.*

NOTE: This paper is based upon an informal discussion at the December, 1925, meeting of the Association, with the addition of information subsequently obtained, and has been put in the form of a paper at the request of the Editor.

Tuberculation of Cast-Iron Pipe. The loss of carrying capacity in cast-iron pipe as a result of tuberculation or incrustation is a very serious matter in some localities, particularly in New England and the Atlantic States. It has been found that in many cases the loss in carrying capacity resulting from such tuberculation has amounted to 40 or 50 per cent. in the course of 20 to 25 years.

This condition is not as a rule accompanied by any material physical deterioration of the cast-iron pipes. We have been told for a long time that cast-iron pipes may be expected to last for a great many years, perhaps even for centuries. This may be true, but the pipes in water-works systems have value only as they are capable of carrying water; and if their carrying capacity has been reduced by one-half, even though the structure may be sound and capable of lasting for a great many years, its value as a part of the water-works plant is very materially reduced.

From time to time we have had this matter called to our attention, more particularly in discussions of the character of the tar coating usually applied to the pipes. Attempts to improve the coating have been made, apparently in some cases with a considerable degree of success, although with soft waters the net result has usually been to retard rather than to prevent the formation of tubercles.

Cement-Lined Wrought-Iron Pipe. Fifty or sixty years ago large quantities of cement-lined and coated wrought-iron pipe were used in the water-works systems in some parts of the country. This type of construction was adoped because cast-iron pipe was then very costly and it was found that the cement-lined pipes could be installed for much less money. Most, if not all, of this early construction involved the use of natural cement. As a rule the useful life of pipes of this type has been found not to exceed 25 or 30 years. This limited life was, however, due to the corrosion of the thin iron shell, and during the life of the pipe little if any loss in carrying capacity occurred except such as might result from the presence of organic growths within the pipes. The character of the interior surface remained substantially unchanged throughout the life of the pipe.

Cement Lining in Cast-Iron Pipe. The possibility of applying cement

* Of Metcalf & Eddy, Consulting Engineers, Boston, Mass.

lining to cast-iron pipe was occasionally discussed, but no serious attempt to line cast-iron pipes extensively was made, so far as the writer has been able to learn, until about the year 1922, when the centrifugal process of applying such a lining was tested. It was found that by this method it was possible to obtain a very thin but extremely smooth cement lining which would adhere to the metal of the pipe with great tenacity.

This process was applied to the "sand-spun" pipe developed by R. D. Wood & Company of Philadelphia, and at about the same time to ordinary cast-iron pipe by the American Cast Iron Pipe and Foundry Company of Birmingham.

The apparatus required is extremely simple and inexpensive. It is believed that no patents are involved. Several of the pipe companies are now prepared to apply the cement lining either to sand cast or centrifugally cast pipe.

Method of Applying Cement Lining. The method now practiced is to insert a long trough or split pipe containing a thin mixture of cement in proper quantity, and invert it within the pipe, which is then rotated at a circumferential speed of about 300 ft. per minute while the cement is spread over the interior surface by placing a pipe or roller against the cement. The rotation is then stopped and the lining examined for uniformity of spreading and additional material inserted if required. The pipe is then rotated again with a circumferential speed of about 600 ft. per minute, which has the effect of driving the solid material (cement and sand) against the wall of the pipe while the water comes to the surface. After a suitable time the rotation ceases and the pipe is rolled away and stored for curing of the cement.

Figures 1, 2 and 3, furnished through the courtesy of the U. S. Cast Iron Pipe and Foundry Company, are general views of the apparatus used. In Fig. 2 the split pipe or trough used for inserting the cement may be seen in the foreground, while in Fig. 3 the men are spreading the cement over the surface of the pipe.

Specifications. The manufacturers have adopted specifications for the cement lining of pipes and fittings, which are appended to this paper.

These specifications should be considered as tentative, and may very probably be modified if experience shall show changes to be desirable, or if the new sectional committee on cast-iron pipe of the American Engineering Standards Committee shall find changes to be advantageous. Cement lining, as well as other coatings, will come within the scope of the work of this committee.

It will be noted that the lining is made up of a cement and sand mixture in the proportion of three parts Portland cement to one part of fine sand, and that the standard thickness of the lining ranges from 1/16 in. for 4-in and 6-in. pipe, to 3/16 in. for 20-in. and 24-in. pipes.

Prices. The present prices charged for cement lining range from about five cents per foot for 4-in. pipe to about thirty-five cents per foot for 24-in.

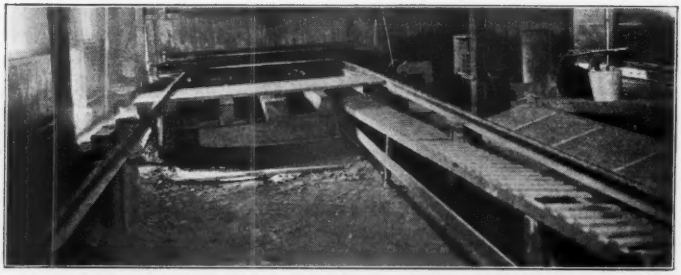


FIG. 1. — GENERAL VIEW OF PLANT FOR LINING CAST-IRON PIPE WITH CEMENT.

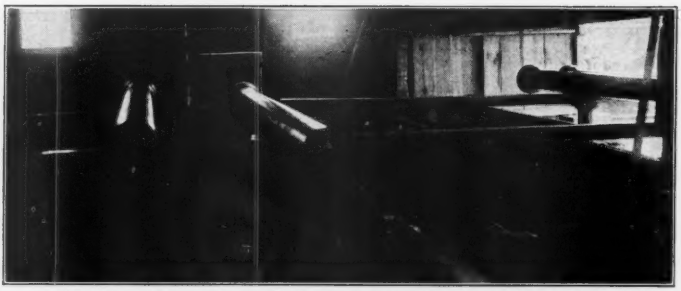


FIG. 2. — TROUGH FOR CEMENT, BEFORE INSERTION INTO PIPE.

FIG. 3. — SPREADING CEMENT IN REVOLVING PIPE.

pipe. Recent quotations from R. D. Wood & Company and the U. S. Cast Iron Pipe and Foundry Company are as follows:

PRICES QUOTED FOR CEMENT LINING IN CAST-IRON PIPE IN CENTS PER LINEAR FOOT. MARCH, 1926.

Size of Pipe, Inches.	R. D. Wood & Co.	U. S. Cast Iron Pipe and Fdry. Co.
4	5	5
6	6⅔	6⅔
8	9½	9½
10	13	13
12	17	17
16	19	19
20	25	25
24	33	35

These prices are obviously insignificant compared with the benefit to be obtained if the lining proves to be durable and to provide a permanent protection against tuberculation.

Experience with Cement-Lined Cast-Iron Pipe. So far as the writer has been able to learn, the longest experience with cement-lined cast-iron pipe is that of Mr. J. E. Gibson, Manager and Engineer of the Water Department of Charleston, S. C. Copy of a report made by him in 1922, upon loss of head and carrying capacity of cast-iron pipes lined with natural cement and with Portland cement, is appended to this paper.

Experience in New England with cement-lined cast-iron pipe appears to be extremely limited. So far as the writer is aware, the earliest experience was that of Mr. Frank J. Gifford at Dedham, Mass., who laid several hundred feet of cement-lined sand-spun cast-iron pipe in 1924, and whose experience with it has been satisfactory. Mr. Gifford calls attention to the fact, however, that no lining can eliminate losses in carrying capacity which may result from accumulations of sand, if such occur in pipes carrying water from driven wells.

Mr. S. H. MacKenzie, Superintendent of Water Works at Southington, Conn., laid a few hundred feet of cement-lined cast-iron pipe in 1925. This pipe was on a dead end and during the early months of its use trouble was experienced from taste in the water. It seems probable that this could have been greatly reduced if it had been feasible to flush the pipe several times when first put in use.

The writer purchased 50 lengths of 6-in. cement-lined cast-iron pipe for the town of Belmont, Mass., which was received in December, 1925. This pipe came from Burlington, Ala., and showed no ill effects from the transportation after being teamed and unloaded without special precautions to avoid cracking the cement. The interior surface was most pleasing, and chisel cuts, made with instructions to the men to treat it roughly, failed to cause the cement to crack or to separate from the iron except for a very minute distance adjoining the cut.

FIG. 4. — CEMENT-LINED CAST-IRON PIPE IN STOCK PILE, BELMONT, MASS.

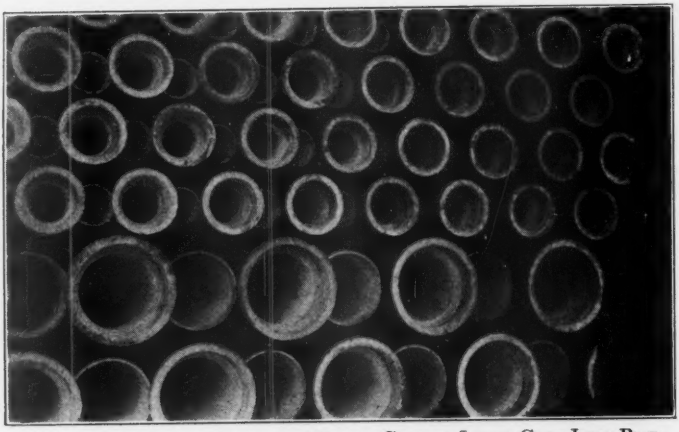


FIG. 5. — ENDS OF 8-INCH AND 12-INCH CEMENT-LINED CAST-IRON PIPE.

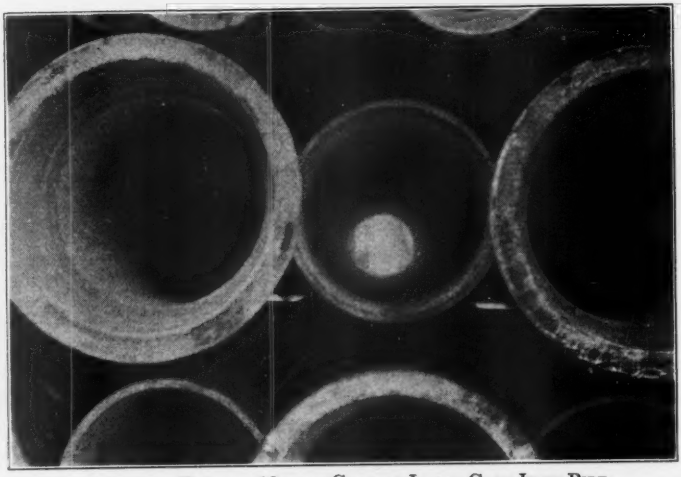


FIG. 6. — ENDS OF 12-INCH CEMENT-LINED CAST-IRON PIPE.

The appearance of this pipe, and the promise of comparatively permanent protection to the material afforded by the cement coating, is such that this type of pipe has been ordered for the entire requirements of the town of Belmont for the year 1926.

Figure 4 shows some of the pipe already received as piled for storage, and Figs. 5 and 6 show the ends of some of the 8-in. and 12-in. pipe. It was impossible to obtain photographs which would give an adequate idea of the appearance of the interior surface.

Only experience extending over a long term of years will demonstrate conclusively that the coating adheres to the material so firmly that no corrosion will take place which can throw off the coating, or that chips of cement resulting from tapping may not cause trouble in meters and house services. It is possible that trouble of this kind may develop, but the writer believes that it is unlikely, and that the probable advantages outweigh the possible difficulties to such an extent that it is advisable to use pipe with cement lining wherever experience has shown that tuberculation of the pipes is a serious matter.

APPENDIX 1.

Specifications for Cement-Lined Cast-Iron Pipe and Fittings.

Cement. The cement used for making the mortar shall be standard Portland cement, complying in all respects with the requirements of the specifications of the American Society for Testing Materials.

Sand. Sand used for the mortar shall be clean, free from organic matter, loam, and other foreign material. It shall be screened, before mixing with the cement, through a screen having a mesh of not coarser than 12 to 1 inch.

Proportion. The mortar used for lining the pipe shall be mixed in approximately the proportions of one part of screened sand to three parts Portland cement by volume. Cement mortar shall be thoroughly mixed, preferably in a power mixer, only sufficient water being added to it to permit of depositing and properly distributing it in the pipes to be coated. The mortar, after mixing, shall be used promptly for lining the pipe, and no mortar that has attained its initial set shall be used.

Preparation of Pipe for Lining. The pipe shall not be coated on the inside with tar or any asphaltum product, but the interior surface shall be thoroughly cleaned of core sand, mud, grease, or other foreign matter, leaving a clean iron surface on which the cement lining is to be applied. Before lining, the pipe shall be hydrostatically tested.

Method of Applying Lining. The lining shall be applied to the interior surface of the cast-iron pipe centrifugally. The mortar shall be spread evenly over the inner surface of the pipe by mechanical means while the pipe is being revolved at a peripheral speed of about 300 ft. per minute. The pipe shall then be allowed to come to rest and a careful examination made for uniformity of lining. Any bare spots may be covered with mortar. The pipe shall then be immediately revolved at a peripheral speed of 600 ft. per minute for a sufficient length of time to obtain a smooth interior surface, due care being taken to avoid the separation of the ingredients. The bottom of the bell and the end of the spigot may be covered with mortar by applying with a brush. All mortar shall be removed from the interior surface of the bell, except as above noted.

Outside Coating. If desired, the pipe may be coated outside with tar or asphaltum coating brushed or sprayed on.

Lining Fittings. The interior surface of the fittings shall be lined by applying the cement mortar with a brush, uniformly and evenly, after which the fitting is to be jarred by rapping it with a hammer until a smooth surface of the lining is secured.

Thickness of Lining. The standard average thickness of lining for various sizes shall be as follows:

Nominal Size of Pipe	Thickness of Cement Lining
4-inch	1/16 of an inch
6-inch	1/16 " " "
8-inch	1/8 " " "
10-inch	1/8 " " "
12-inch	1/8 " " "
16-inch	1/8 " " "
18-inch	3/16 " " "
20-inch	3/16 " " "
24-inch	3/16 " " "

A tolerance of $^1/_{32}$ in. in thickness of lining shall be permitted on 4-in. and 6-in. pipe and a tolerance of $\frac{1}{16}$ in. on sizes from 8-in. to 24-in.

Thicknesses other than standard can be furnished if desired.

Curing Cement Lining. The cement-lined pipe shall be immediately protected in a suitable manner from the direct rays of the sun. To prevent too rapid drying, suitable means shall be provided to keep lining damp for a period of at least 24 hours. During this period when lining is sufficiently set, it shall be thoroughly wet down. In cold weather, proper precaution shall be taken to prevent freezing.

No pipe shall be shipped until the lining is thoroughly hard, and in no case shall shipment be made in less than 48 hours.

APPENDIX 2.

REPORT BY J. E. GIBSON, MANAGER AND ENGINEER, WATER DEPARTMENT, CHARLESTON, S. C.

SUBJECT: Determinations of the Coefficient "C" in Hazen and Williams' Formula for Cement-Lined Cast-Iron Pipe.

The Charleston Water Department had experienced for years a material falling-off in the carrying capacity of the cast-iron mains throughout its distribution system. This was particularly called to their attention in the constantly increasing friction head of their twelve miles of 24-in. cast-iron main between their pumping station and the center of distribution. This main had been cleaned three times, with the result that after each cleaning the friction losses increased very much more rapidly, and in the last cleaning 80 per cent. of the results from cleaning had been overcome within 30 days after cleaning. That is to say, the coefficient after cleaning had been restored to practically that of new cast-iron pipe, but within 30 days after the date of cleaning this coefficient had again decreased until it was practically the same as that before cleaning. Several miles of 6-in. main had been cleaned in the city distribution system, with the result that after a year's service these mains had practically returned to the condition, so far as carrying capacity was concerned, as that of immediately preceding the cleaning.

Realizing that from an economical standpoint it would be necessary for the Department to install some form of pipe that would not tuberculate or corrode up so rapidly, and being familiar with cement-lined wrought-iron mains as laid by the late George H. Norman and the American Pipe and Construction Company of Philadelphia, under the Phipps Hydraulic Pipe Patents, the Department took up with the American Cast Iron Pipe Company of Birmingham the question of lining standard cast-iron pipe. The American Cast Iron Pipe Company's Research Department was favorably inclined and, as a result, built an experimental plant and undertook to manufacture standard cast-iron pipe, cement-lined. The pipe, as first manufactured, was lined with natural or Rosendale cement, the lining being $\frac{3}{16}$ in. in thickness for pipe 4 in. to 10 in. in diameter and $\frac{1}{4}$ in. in thickness for pipe 12 in. to 24 in. in diameter. The Department purchased some 40 000 ft. of this class of pipe, and to determine the value of the coefficient "C" in Hazen and Williams' Formula tested 6-in. and 16-in. pipe a few weeks after laying and repeated the tests on the 16-in. pipe 12 months later, to see if any material change had occurred in this coefficient due to the age of the pipe. For description of the process of lining, see *Engineering News Record*, September 7, 1922.

Method of Lining. Within the past 12 months or so the method of lining the pipe has been materially improved, the present process being to use Portland cement and spin it onto the pipe by centrifugal force. The result has been that it has been possible to reduce the thickness of the lining and to improve the quality of the material. In the present pipe the cement, due to the centrifugal vibratory action, adheres very tenaciously to the inner surface of the pipe and there is sufficient water driven to the inner surface of the cement-lining so that the coating resembles very much that of porcelain. This lining, as before stated, is much superior to that originally purchased by the Department, and since the centrifugal process of lining has been adopted the Department has purchased some 10 000 ft. of 6-in. main and recently completed a test to determine the coefficient "C", Hazen and Williams' Formula, on this new type lining. The results of all of these tests are given in tables 1, 2, and 3 herewith.

TABLE NO. 1.

Six-in. Cement-Lined Pipe, Using Natural or Rosendale Lining $\frac{3}{16}$ in. Thick. Internal Diameter of Pipe after Lining $5\frac{5}{8}$ in. Standard 4-in. Crest Type Meter Used to Measure Quantity of Water and Carbon Tetrachloride and Mercury Manometer to Measure Loss of Head. Length of Pipe Tested 500 ft. Date of Test — December, 1922.

Flow in 1 000 Gal. per 24 Hours.	Velocity in Ft. per Second.	Loss of Head per 1 000 Ft.	Value of "V" in Hazen and Williams' Formula.
134.4	1.20	1.08	141
185.26	1.66	2.34	128
299.44	2.68	4.90	138
369.45	3.31	7.25	139
457.78	4.41	10.76	139
496.34	4.45	12.55	139
		Average —	137

TABLE NO. 2.

Test of 16-in. Pipe Lined with ¼ in. Natural or Rosendale Lining, internal Diameter of Pipe 15½ in. Test Made by Using Pitot Tubes to Determine Quantity of Water, and Carbon Tetrachloride and Mercury Manometers to Measure Friction Losses. 500 ft. of Main Tested.

Flow in 1 000 Gal. per 24 Hours. Test		Velocity in Ft. per Second. Test		Loss of Head per 1 000 Ft. Test		Value of "C" in Hasen and Williams' Formula. Test	
Dec. 1922	Dec. 1923	Dec. 1922	Dec. 1923	Dec. 1922	Dec. 1923	Dec. 1922	Dec. 1923
766	....	0.89	....	0.27	....	128	...
....	768	....	0.89	....	0.21	...	133
....	1 066	....	1.24	....	0.41	...	128
....	1 127	....	1.31	....	0.46	...	128
1 157	....	1.34	....	0.44	....	134	...
....	1 342	....	1.56	....	0.64	...	128
....	1 505	....	1.75	....	0.80	...	127
1 632	....	1.89	....	0.77	....	140	...
1 726	....	2.01	....	0.89	....	137	...
....	1 958	....	2.28	....	1.34	....	125
....	2 100	....	2.44	....	1.45	...	128
				Averages		135 and	128

The coefficients obtained in the above table we consider confirmatory and within the limits of observation when the method of measuring the quantity of water is considered.

The losses of head, columns 5 and 6, are accurate whereas the columns 1 and 2 may have errors, due to the limiting accuracy of the Pitot tubes.

TABLE NO. 3.

Test of 6-in. Cement-Lined Cast-Iron Pipe, Portland Cement Lining, Centrifugally Placed. Thickness of Lining $\frac{1}{16}$ in. Net Internal Diameter $5\frac{7}{8}$ in. Section Tested 250 ft. Water Measured by Standard Disc Type Meter. Carbon Tetrachloride and Mercury Manometer Used to Measure Friction Loss. Tested August, 1924.

Flow in 1000 Gal. per 24 Hours.	Velocity in Ft. per Second.	Loss of Head per 1000 Ft.	Value of "C" in Hazen's and William Formula.
149.8	1.23	1.34	124.8
180	1.45	1.72	131.1
299.5	2.46	3.79	142.5
407.4	3.35	6.56	143.8
498	4.09	9.23	146.2
597	4.91	13.11	145.3
683	5.61	16.8	145.3
		Average	137
		Average last five tests	144.5

In the above table the two first lines represent results using carbon tetrachloride of $1\frac{1}{2}$ specific gravity, and the fluctuations in the columns were so great as to make it difficult to read satisfactorily. Therefore, we feel that these results are not nearly so representative or dependable as the tests indicated by the last five where mercury manometer was used, and the oscillations of the column were reduced to a negligible quantity.

Testing Apparatus Calibrated. In the foregoing tests all apparatus was calibrated and piezometric pipe was used to connect the ends of the sections of pipe under test so that all readings were made at one point and simultaneously. The meters were calibrated and in the case of the 16-in. pipe where Pitot tubes were used, check calibrations were made before and after test to obtain velocity coefficients. All tests are figured upon the actual net internal diameter of the pipe, and each test reported represents the algebraic average of one-half minute observations for five and ten minute periods.

Our experience, covering a period of about three years, shows that the pipe is not incrustating or tuberculating, the carrying capacity is being maintained, and no difficulty is being experienced in tapping or cutting the pipe. A number of Smith taps have been made where the section cut out by the cutter permits of examination, showing that the cement-lining is tenaciously adhering to the cast iron without tuberculating or rusting underneath the coating.

The Department now has in service ten miles of cement-lined cast-iron mains from 4 in. to 24 in. in diameter.

PROCEEDINGS.

DECEMBER MEETING.

ROOMS OF THE TWENTIETH CENTURY CLUB,
3 JOY STREET, BOSTON, MASS.

Tuesday, December 8, 1925.

The President, Theodore L. Bristol, in the chair.

SECRETARY GIFFORD. At this morning's meeting of the Executive Committee, the following men were elected members: Kenneth Shibley, Seattle, Wash.; Edgar Philip Cable, York, Penn.; Frank A. Gay, Manchester, N. H.; Frank T. Hook, Malden, Mass.; Arthur P. Gallant, Newtonville, Mass.

Complying with your request at the last meeting, after the election of Leonard Metcalf as an honorary member I wrote him, and received a reply from him; both communications I have here, and have been requested to read them by the Committee.

November 11, 1925.

My dear Mr. Metcalf:

I have the honor to notify you that at a meeting of the Executive Committee of the New England Water Works Association, held on Tuesday, November Tenth, Nineteen Hundred and Twenty-five, you were elected an Honorary Member.

Following the announcement of your election at the meeting of the Association, on the same day it was moved by Robert Spurr Weston, seconded by Frank A. Barbour, and voted unanimously by rising, that when notifying you of your election the Association and its individual members express to you their kindest greetings; their profound admiration for you as man and fellow workman; their respectful wonder at your continued service in spite of pain; and, above all, their sympathy and love for you, the friend of so many for so many years.

Your devotion to duty and courageous detachment of spirit has been a wonderful inspiration to all your friends. It helps them to realize in truth that the "things of the spirit are eternal," and the sufferings and pains of the body may but emphasize the triumph of the soul.

Adding my heartiest personal greetings, I remain

Yours sincerely,

(Signed) FRANK J. GIFFORD,
Secretary.

To Mr. Leonard Metcalf, Concord, Mass.

And this is the reply:

Concord, Mass., November 13, 1925.

Mr. Frank J. Gifford, Secretary,
New England Water Works Association,
715 Tremont Temple, Boston, Mass.

My dear Mr. Gifford:

I was deeply touched by the action of the New England Water Works Association in electing me to honorary membership, and by your letter transmitting the message of the Association to me.

Knowing the splendid record of service of the Association, its sturdy membership, and the illustrious men whom it has seen fit to honor in the water-works field, I am deeply sensible of the action taken.

For many years I have had great pleasure in working in this Association and in the acquaintanceship which it has brought me amongst the water-works men, and have always valued the friendly relations which I have had with them.

I feel confident of the future of the Association because there is still a good field for its work if the younger men can but be brought into contact with its past and present activities.

I am very glad if anything that I have done may have helped others.

With greetings to all, I am,

Cordially yours,

(Signed) LEONARD METCALF.

A paper on "Periods of Storage and Microscopic Organisms in Reservoirs" was read by Robert Spurr Weston, Consulting Engineer, Boston, Mass.

Secretary Gifford invited discussion relative to the next meeting-place of the Association, and after an informal vote it was decided to hold the next meeting at the rooms of the Twentieth Century Club, 3 Joy Street, Boston.

A paper on the "Substitution of Machinery for Hand Labor in Pipe Laying," illustrated, was read by Stephen H. Taylor, Superintendent, Water Department, New Bedford, Mass. David A. Heffernan, Patrick Gear and John C. Chase participated in the discussion.

A progress report of the Committee on Standardization of Cast Iron Pipe was presented by Frank A. McInnes.

Henry T. Gidley, Superintendent, Fairhaven Water Company, gave an illustrated talk on "The Fire which Destroyed the Office and Shop of the Fairhaven Water Company." Patrick Gear and Samuel Harrison participated in the discussion.

(*Adjourned.*)

JANUARY MEETING.

ROOMS OF THE TWENTIETH CENTURY CLUB,
3 JOY STREET, BOSTON, MASS.

Tuesday, January 12, 1926.

The President, Theodore L. Bristol, in the chair.

SECRETARY GIFFORD. At this morning's meeting of the Executive Committee, B. Nicoll & Co., Inc., of 294 Madison Ave., New York City, was elected an associate member.

The Executive Committee have requested me to announce that the annual convention for 1926 will be held at Providence, Rhode Island. (*Applause.*) The date will be announced later, after arrangements have been completed.

THE PRESIDENT. Mr. Symonds would like to make an announcement with reference to an amendment to a bill that is to be proposed before the General Court.

HENRY A. SYMONDS. Mr. President: During the last two seasons of extremely dry weather some of the water companies in Massachusetts have attempted to take advantage of the so-called Emergency Act of the Legislature, assuming that under that Act they had the right to take water from any ponds or streams or other possible sources of supply. But it was found that for some reason the water companies had been omitted from that Act.

There seems to be no logical reason for this, and it places the water companies in rather an embarrassing position; in some cases that I am familiar with they have been obliged to disregard their legal rights and take waters from areas in which they had no proper rights.

Now, the taking of water under the original Act is entirely subject to the approval of the State Department of Health, and to remedy this apparent omission or defect in the Act an amendment has been drafted, simply including water companies in the list with the municipal organizations that are able to take advantage of this Act.

The Act is very short, but I will not take the time to read it. The only point which calls for any special consideration (outside of the main question of the companies to be included) is what organization or what authority shall have the power to say when an emergency of this kind exists. In the municipal plants the commissioners, the selectmen, or the municipal authorities have the right to assert that an emergency exists. It seemed that perhaps the best way to handle this was to leave it with the State Department of Health, and as the proposed amendment is drafted it will read:

"Water Companies shall not make such taking or purchase unless they have been first so ordered in writing by the State Department of Public Health."

And then at the end:

"The vote of a city council or of the inhabitants of a town or of the Metropolitan District Commission or the written order of the State Department of Public Health to a Water Company to make or authorize such taking or purchase shall be conclusive evidence of the existence of the emergency."

This is not primarily an Act for the water companies, although it would relieve the water companies of some embarrassing positions. Of course in case of a shortage, the shortage is felt by the community that is being supplied, whether it is by a municipal department or by a company; and from the point of view of both it seemed that this right should be included in the Emergency Act.

I presume that a proposed Act of this kind will automatically be referred to your committee.

CHARLES W. SHERMAN. Mr. President: In view of the possibility that this proposed amendment of Mr. Symonds may come up for a hearing before the next meeting of the Association, it seems to me that it would be wise (if the legislation is desirable, and I believe it is) that our committee should have the authority of the Association to appear before the legislative committee in behalf of the amendment.

I therefore move that the Association authorize its committee to appear before the legislative committee in behalf of the amendment proposed by Mr. Symonds.

PATRICK GEAR. Mr. President: There is another bill before the Legislature that I was going to speak of after Mr. Sherman had read his paper. That is the general bill which extends the time from fifteen to thirty years for cities or towns to borrow money for the extension of their water plants — instead of fifteen years, as at present. It used to be five years, but Mr. Sherman got a bill some two or three years ago and put it through the Legislature (without any help from anybody, I guess), making it fifteen years. I would like to have included in that motion of his that this committee of the New England Water Works Association should also appear in behalf of that bill to extend, from fifteen to thirty years, the borrowing of money to lay main pipes 16 in. in diameter. I would like to have the Association ask our committee to appear for that bill, of which we will have notice.

The bill is introduced in the Legislature and we will be notified when the hearing comes, and if there are any cities or towns that are interested in that bill I would like to have them appear. As the bill says, we have got to have the money.

MR. SHERMAN. Mr. President: As Mr. Gear said, the matter was unofficially taken up with me a month or two ago, and I outlined a formal amendment to the general bill which I thought Holyoke would like to introduce. The purpose of it, as he has stated, is to make it possible to borrow for longer periods when the main supply pipes are 16 in. or larger in diameter.

I think that, perhaps, ought to be a separate vote, Mr. President, rather than on the original motion.

THE PRESIDENT. Are there any other remarks in reference to the amendment proposed by Mr. Symonds?

The motion was carried unanimously.

MR. SHERMAN. Now I make the other motion, Mr. President: That the committee be also authorized to appear in favor of the bill which we understand is to be introduced by the city of Holyoke, extending the time, for borrowing money to lay pipes 16 in. or larger in diameter, to thirty years, instead of fifteen years, as at present.

The motion was duly seconded, and carried unanimously.

A paper on "Improvement of the Keene, N. H., Water Works," illustrated with stereopticon views, was read by Robert Spurr Weston and George A. Sampson.

Desmond Fitzgerald, A. R. Hathaway, Henry A. Symonds, Mr. Sperry, Prof. Richard Tyler, Patrick J. Lucey, Joseph Conners, and Frank B. Northrop participated in the discussion.

A paper on "Economy of Municipal Bonds for Water Works Construction" was read by Charles W. Sherman.

(Adjourned.)

February Meeting.

Rooms of the Twentieth Century Club,
3 Joy Street, Boston, Mass.

Tuesday, February 9, 1926.

The President, Theodore L. Bristol, in the chair.

Secretary Gifford. At this morning's Executive Committee meeting the following men were elected to membership: Albert W. Moore, Hingham, Mass.; Edward Francis Toumey, Lynn, Mass.; Andrew S. Merrill, Bath, Me.

The Committee on the Annual Convention have selected the dates September 14 to 17, inclusive, for the convention, at Providence, Rhode Island. In all probability the headquarters will be at the Biltmore Hotel.

The Executive Committee this morning authorized the President to appoint a committee on memoir for Leonard Metcalf, and the president subsequently appointed Charles W. Sherman and William Wheeler as that committee.

Mr. Frank Hall, will you please rise? (*Mr. Hall stands, amid applause, everybody rising.*) For the benefit of the younger and newer men I will say that Mr. Frank Hall is one of the original charter members of this Association.

An illustrated paper on "Tampa's New Water Works" was read by Nicholas S. Hill, Jr., Consulting Engineer, New York City. S. Pincus, Almon L. Fales, E. Sherman Chase, and Frank A. Marston took part in the discussion.

A discussion on "Red Water" was opened by Robert Spurr Weston and participated in by David A. Heffernan, W. A. MacKenzie, Samuel A. Agnew, Henry T. Gidley, Joseph Conners, George A. Sampson, Stephen H. Taylor, Percy R. Sanders, and Nicholas S. Hill, Jr.

(*Adjourned.*)

March Meeting.

Rooms of the Twentieth Century Club,
3 Joy Street, Boston, Mass.

Tuesday, March 9, 1926.

The President, Theodore L. Bristol, in the chair.

Secretary Gifford. At the Executive Committee meeting this morning the following were elected members of the Association: Howard M. Beverly, Ayer, Mass.; Walter V. Howes, Winsor, Conn.; Fred Royce Ackley, Nashua, N. H.; George E. Gomley, Abington, Mass.; Arthur Baker Graves, Nashua, N. H.; Philip Edgar Bond, Holyoke, Mass.

Corporate Membership, Chicopee Water Board, Chicopee, Mass.

Also at their meeting the Executive Committee appointed the committee for the June outing, as follows: Frank L. Northrop, George C. Brehm, Morrison Merrill, Roger W. Esty, Charles J. Crump.

The President. According to the by-laws, "at the business meeting of March the Association shall elect a nominating committee of five members who shall report to the Secretary before the first day of June, a list of nominations for officers to be elected for the ensuing year. This report shall be printed and mailed by the Secretary to the membership of the Association on or before June 15."

Will you nominate members for a nominating committee? I think heretofore it has been done by the President, — that is, you have delegated your authority to him. I do not want the authority and I shall refuse to accept it, so that it is up to you to nominate five members for the nominating committee.

The following members were nominated from the floor; upon motion duly made and seconded, it was voted to close the nominations, and the members named were duly elected as the nominating committee: George H. Finneran, Charles W. Sherman, Richard D. Chase, George W. Batchelder, William F. Sullivan.

Papers on "The Massachusetts Water Report" were presented by Allen Hazen, Consulting Engineer, New York City, and Colonel Charles R. Gow, Chairman of the Metropolitan Water Supply Investigating Commisssion.

The subject of cleaning reservoirs was brought up by Mr. John P. Miller and discussed by Mr. Miller and George F. Merrill.

A rising vote of thanks was given to Mr. Hazen and Colonel Gow.

(*Adjourned.*)

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Dear Sir: Enclosed please find $\frac{\$.75}{1.50}$ in payment of charge for Certificate $\frac{}{2.25}$ of Membership in the N. E. W. W. Association ($1.50), and Membership Button ($1.00), which please mail me and oblige

Yours truly,

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General Contractors
Specializing in Water Works
31 NORTH SQUARE
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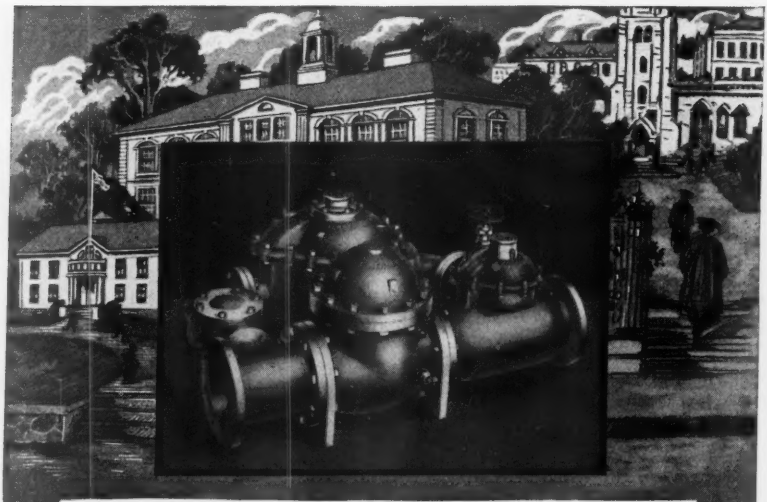

287,804 SCHOOL BUILDINGS

are worth less than half the value of the property this Meter protects

THE HERSEY DETECTOR METER is installed on fire services protecting nearly $5,000,000,000 worth of property, or a sum over 50% in excess of the value of the 287,804 school buildings in the United States.

Not theory but the practical experience of 20 years has gained the unrestricted acceptance of the Hersey Detector Meter for every kind of fire service by every insurance company, stock and mutual, in the country and more than 800 water departments and water companies.

This record has no equal.

HERSEY WATER METERS

HERSEY
Manufacturing Company

Main Office & Works: Corner E and 2nd Sts., South Boston, Mass.

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FROZEN!—but not damaged

Here is an actual photograph of a LAMBERT Frost-proof Meter which has been frozen to an extent that would put the ordinary meter completely out of commission.

This is made possible by a patented, non-corrosive yielding bolt device which allows the upper and lower casing, disc chamber and gear train to part without damaging the meter in any way. Five minutes' labor the only repair cost.

The expense and annoyance from frozen water meters can be eliminated for all time through the installation of the LAMBERT Frost-proof.

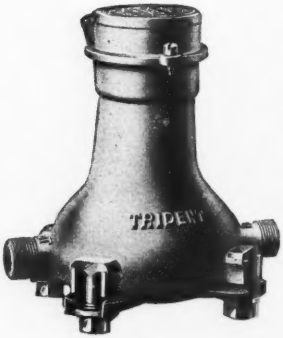
It has been proved that the LAMBERT is the easiest water meter to take apart and put together again as well as the simplest, most reliable and accurate.

If you are interested in other types of meters, we make one for every requirement.

THOMSON METER COMPANY

SALES OFFICE: 50 EAST 42nd STREET, NEW YORK CITY, N. Y.

LAMBERT FROST-PROOF METERS



PROFITABLE CONTROL

PERFECT co-ordination of the working units of Trident Meters, in accurately measuring water consumption over a long period of years, is due to quality materials and precision methods of manufacture. These must pass one hundred per cent inspection.

This is why Tridents have been so profitably conserving the water supplies of cities and municipalities throughout the world for the past thirty-four years. It's not the first cost of meters that counts—it's the design, materials, construction, and low maintenance cost of Tridents that pays and saves throughout the years.

Results, where Tridents have been in constant use for many years, will convince as to their absolute accuracy in long service with minimum repairs or replacement of parts.

AQUAFAX is a 56-page, monthly magazine giving current news and accurate information regarding the conservation of water. The regular subscription price is $1.00 per year, but it will be sent free upon request to engineers, municipal heads and civic organizations.

Send for a copy of the 86-page book illustrating and describing all types and sizes of Neptune Trident Meters.

NEPTUNE METER COMPANY

Pioneers in Meter Progress

50 EAST FORTY-SECOND STREET, NEW YORK CITY

NEPTUNE METER CO., LTD., 1197 KING ST., WEST, TORONTO, ONT.

Boston	San Francisco	Los Angeles	Portland
Chicago	Atlanta	Seattle	St. Louis, Mo.

WATER METERS

The TROPIC — An all-bronze Water Meter, with connection spuds attached to the lower case. Particularly designed for warm sections of the country.

TROPIC

ARCTIC

The ARCTIC — A frost-bottom meter, especially designed for cold sections of the country.

These two meters embody exactly the same mechanical features, the only difference being the changes necessary to provide a frost breaking feature in the Arctic.

Either of these meters will be equipped with a COMPLETELY ENCLOSED intermediate train RUNNING IN OIL, if desired.

Write or wire nearest office for full information.

Please Note Change of Address

PITTSBURGH METER COMPANY

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SALES OFFICES:

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Worthington Water Meters

The Worthington meter line is complete. It includes a meter for every possible service and condition.

Disk Meters—both frost-proof and for warm climates

Turbine Velocity Meters

Compound Meters

Hot-water Meters for boiler-feed lines

Oil Meters

Stocks of meters and parts are carried in our branch houses in all parts of the country. Write for bulletins.

The Worthington Waterworks Line

Pumps, steam and power, reciprocating and centrifugal

Pumping Engines, horizontal cross-compound and vertical triple expansion, crank and fly-wheel and direct-acting

Condensing Apparatus, surface, jet, barometric

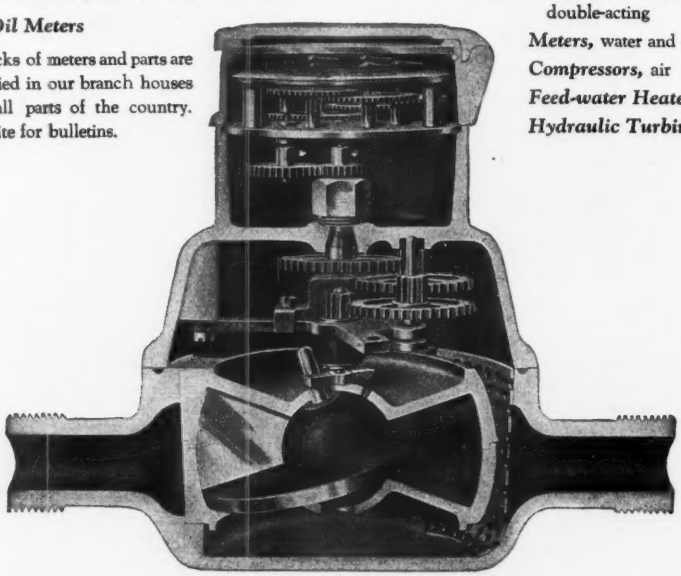
Diesel Oil Engines, horizontal and vertical, two-cycle and four-cycle, single and double-acting

Meters, water and oil

Compressors, air

Feed-water Heaters.

Hydraulic Turbines



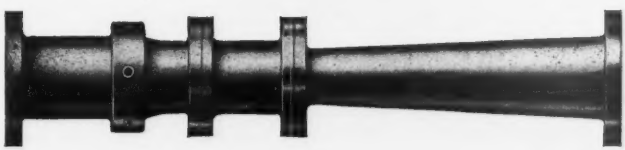
WORTHINGTON PUMP AND MACHINERY CORPORATION
115 BROADWAY, NEW YORK CITY
BRANCH OFFICES IN 24 CITIES

WORTHINGTON

7183-3

SINCE 1891

when the first installation in the world was made by the East Jersey Water Co., the VENTURI has continued to meet the demand of American Water Works practice for an ACCURATE, PRACTICAL, and DEPENDABLE METER for main pipe lines.



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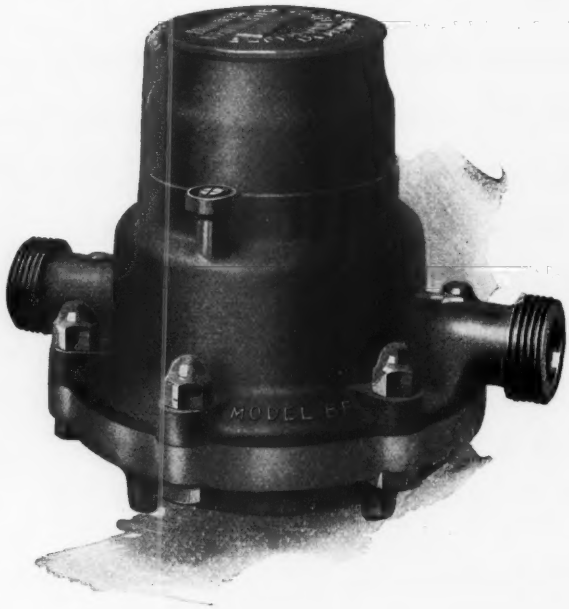
PROVIDENCE, R. I.

AMERICAN AND NIAGARA
WATER METERS



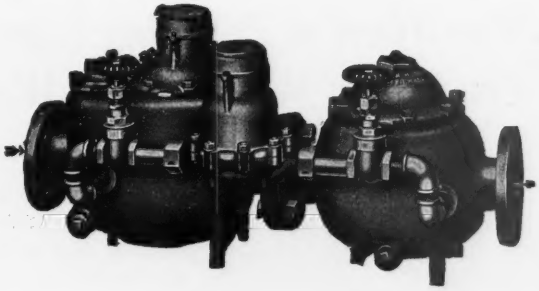
American and Niagara meters are made in solid casing types and frost bottom types. The illustration above shows a 5/8" x 3/4" meter of the frost bottom type. Those meters having bronze outside casings are known as Americans and those having galvanized cast-iron outside casings are Niagaras. The works in all the different casings are of one best model and interchangeable. The registers may be either round reading or straight reading and may indicate cubic feet, U. S. gallons, imperial gallons or litres. All Niagara and American meters are tested and adjusted according to the requirements of the Standard Specifications for water meters adopted by the New England Water Works Association and the American Water Works Association.

Write for large catalog and prices.

BUFFALO METER CO.

ESTABLISHED 1892

2896 Main Street **BUFFALO, N. Y.**



The New Nilo

The new improved **Nilo Compound Meter** now comes equipped with a bronze body. This is a valuable addition to meter service for it eliminates the danger of corrosion and filling up due to the collecting of corrosive matter. Bronze being stronger than iron the gross weight of the meter is less, making it easier to transport, handle and install.

It also has two gate valves which allow the removal of the by-pass meter for cleaning or repairing without shutting off the line.

The controlling valve mechanism of the new **Nilo Compound Meter** is self contained and easily detached from the main body casings.

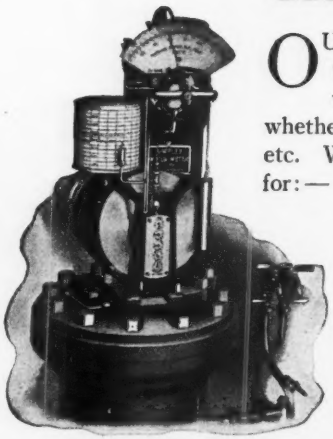
These three improvements make the **Nilo,** a long standing favorite, the unrivaled leader in its field.

UNION WATER METER CO.

Incorporated 1868

WORCESTER, MASSACHUSETTS

Is Your Pressure Low?
Are You Short on Pumping Capacity?
Do You Know Where Your Water Goes?



OUR Engineering Department will tell you how to determine your water distribution, how to find out whether or not new mains are required, etc. We can supply you with the means for:—

1. Checking up pump performance and determining slippage due to leaky plungers, defective valves, short stroking or other causes,
2. Measuring delivery of centrifugal pumps and figuring whether or not the station is up to efficiency,
3. Distributing proportionately the cost of water supplied to several districts,
4. Checking up the performance of filter beds,
5. Detecting waste or pipe leakage,
6. Recording daily amounts of sewage handled and planning future extensions, etc., etc.

THE SIMPLEX METER

VENTURI, PITOT TUBE OR ORIFICE TYPES

THE importance of exact measurements by means of a Simplex Meter cannot be over emphasized. Mr. Jeffries, Chairman of the West Chester, Pa. Water Works Committee, was able, by checking the performance of his pumping engine with a Simplex Meter, to discover that due to the imperfection and wear in the valves the slippage amounted to 300,000 gallons of water per day. This represented a daily loss of $30.00, or in other words a daily saving of $30.00, or $900.00 per month, when the valves were put in order. The Simplex Meter thus paid for itself in a month's time.

Frequent repeat orders from satisfied customers who formerly used other meters are the best evidence of merit of the Simplex Meter.

We have had many years' experience in solving water flow problems involving all sorts of conditions, and we are at all times prepared to submit general layouts involving cost and capacity, and to make explicit and complete recommendations. Write for Bulletin N26.

SIMPLEX VALVE AND METER COMPANY

Manufacturers of Meters for Water, Sewage, and Other Liquids, Rate Controllers, Automatic Air Valves, Regulating Valves, and Hydraulic Apparatus of Special Design.

6757 UPLAND STREET PHILADELPHIA, PA.

"WATCH DOG" WATER METERS

ACCURATE *DURABLE*

DISC, CURRENT AND COMPOUND TYPES

Inquiries Solicited

GAMON METER COMPANY

NEWARK NEW JERSEY

DISC METERS

NASH TYPE K

Wherever the specifications call for a disc meter, we confidently recommend the NASH, an all bronze model, with every worthwhile feature to be expected in a meter of this style.

FROST PROTECTION

The breakable flange washer of the NASH is a practical and economical detail. These washers which are renewable at trifling cost, give way in the event of freezing, allowing the sections of the casing and measuring chamber to part, thus protecting the working portions.

A GREAT CONVENIENCE

If you have ever been bothered trying to get at the inside of an obstinately stuck meter, ask our man to show you how easily NASH Type K can always be opened and examined.

Let us send you a circular which fully describes and illustrates this substantial and reliable meter. Ask for No. 200.

NATIONAL METER COMPANY

299 BROADWAY, NEW YORK

Chicago Boston Cincinnati Atlanta San Francisco Los Angeles

There is a complete line of Badger Water Meters from the small 5/8" disc type to the large 6" Turbine Compound. You will find a type and size Badger for every service.

The Proven Water Meter

You can conscientiously specify Badger Meters and be assured that they will perform dependably and accurately day after day. They have been tried, tested and have proven themselves. That is why they are being used in ever increasing numbers, the country over.

Badger Meters give satisfactory service because they are carefully constructed. They are intended to give long life, and they do.

We are always glad to render advice on meter systems and stand ever ready to demonstrate the superiority of Badger Meters — theoretically, structurally, mechanically and practically. Let us send you special circulars giving detailed information.

Badger Meter Mfg. Co., 853 30th St., Milwaukee, Wis.

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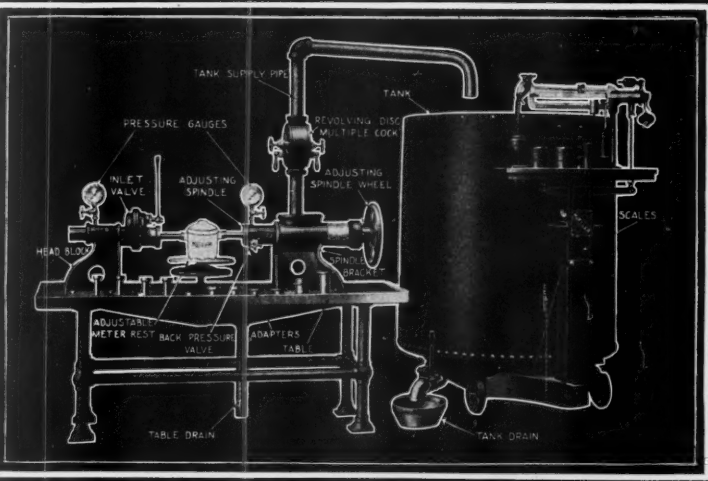
4038 Arcade Bldg., Seattle, Wash.

BADGER METERS

Faithful to the last drop



The People Demand Increased Efficiency

You can make sure your Department gets full revenue for every gallon of water used—by seeing that all meters are regularly tested for accuracy—with the

Mueller Water Meter Tester

The Mueller will prove exactly what each meter does—will enable you to adjust each meter to absolute accuracy—will save more than its cost year after year. Used and endorsed by leading municipalities. The name Mueller guarantees both Quality and Service.

Detailed description and prices on request.

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Phone Bell 153—Auto 2131

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WATER WORKS
OF NEW ENGLAND

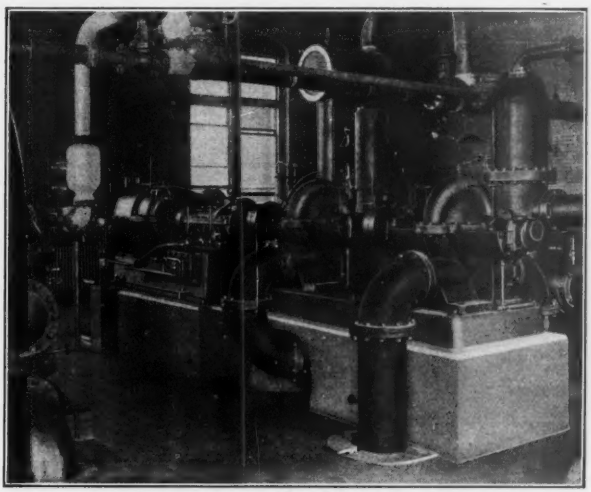
A few reasons why we solicit your inquiries on Water-Works Pumping Equipment:

First. — We make a specialty of furnishing Complete Water-Works Pumping Units of all types.

Second. — Total responsibility of installation is assumed by us.

Third. — We relieve the purchaser of every detail and turn the complete unit over to him under actual operation and with guarantee.

Fourth. — Every unit installed to date has exceeded its guarantee and has been completely accepted.



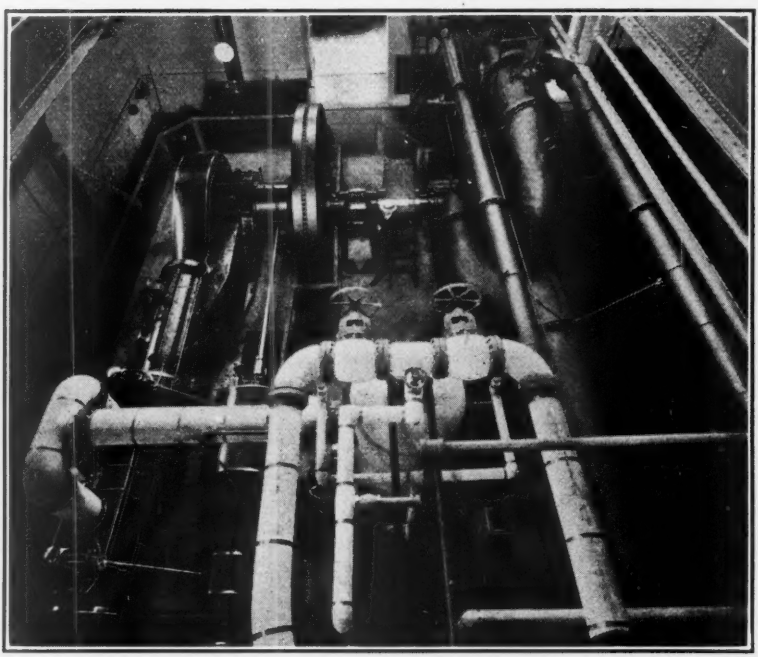
Turbine-driven Pump at the Arlington Station of the Metropolitan Water Works, Boston, Mass.

F. A. Mazzur & Co.

141 MILK STREET, BOSTON

A Notable Pump Installation at Ward Street, Boston

FOR METROPOLITAN DISTRICT COMMISSION



View of 36″ Morris Machine Works Pump with direct connected 24″ x 40″ Nordberg Uniflow Engine. This unit delivers 50,000,000 gallons per 24 hours against 45 feet dynamic head at 150 rpm. Duty Guarantee 107,000,000 foot lbs. per 1000 lbs. of dry saturated steam used at 150 lbs. pressure and with 4″ absolute vacuum.

The complete equipment including condenser, primary heater, special valves and fittings furnished under one contract and responsibility and to the direction of Mr. F. D. Smith, Engineer of the Metropolitan District Commission.

Starkweather & Broadhurst, Inc.

ENGINEERS AND CONTRACTORS

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Pumping Plant Contractors

CENTRIFUGAL, POWER, STEAM PUMPS

STEAM TURBINES
WATER WHEELS

ELECTRIC MOTORS
OIL ENGINES

RAY ENGINEERING COMPANY
136 FEDERAL STREET
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Power Plant Equipment
Steam and Heating Specialties

For new pumping equipment guaranteed by people who will make good, phone, wire or write the above.
Sales Agents for UNION STEAM PUMP CO.

Standpipes
Water Tanks
Gas Holders
and all other metal surfaces need the protection of
DIXON'S
Silica-Graphite
PAINT
BOOKLET NO. 87-B
JOSEPH DIXON CRUCIBLE CO. Jersey City, N. J.

WE announce our appointment as Sales Representatives of DAYTON-DOWD COMPANY, of Quincy, Ill., Manufacturers of Centrifugal Pumping Machinery. After exhaustive investigation, we present this line of equipment to the Trade in New England as being of the highest grade and thoroughly modern in design and manufacture.

We are prepared to furnish DAYTON-DOWD pumps in all sizes and for all classes of service, in steam, motor, gasoline and belt drive types, and solicit your inquiries, assuring you of our best efforts in your sales and service requirements, and of our appreciation of your continued confidence and patronage.

POWER EQUIPMENT CO.

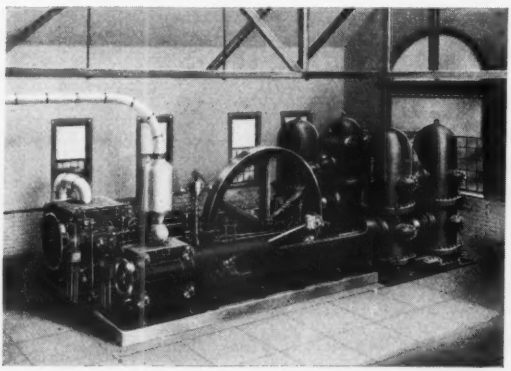
131 State Street, **Boston, Mass.**

MURRAY IRON WORKS CO.

(INCORPORATED 1870)

BURLINGTON, IOWA, U. S. A.

Builders of High Duty Pumping Engines



Murray High Duty Crank and Fly Wheel Pumping Engine, Opposed Type

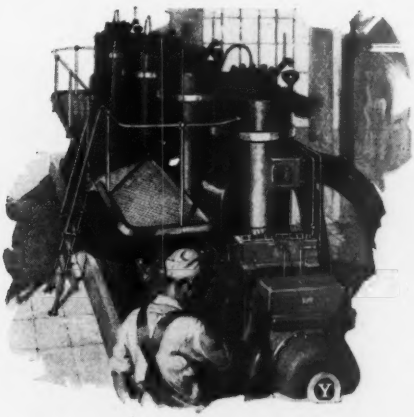
Engineers, Iron Founders, Boiler Makers

Corliss and Una-Flow Engines

Water-Tube, Fire-Tube and Internal-Furnace Boilers

Builders of Complete Power Plants

PLEASE SEND US YOUR SPECIFICATIONS AND CALLS FOR BIDS



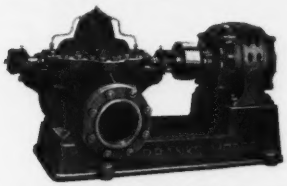
More than 90,000 h.p. *in Pumping Stations alone*

Over 90,000 horsepower of Type "Y" Engines are today furnishing power for pumping stations and the number is constantly increasing.

This steady change to Type "Y" Diesel power is the natural result of operation economies that have been accomplished during the past ten years.

In waterworks service, the Type "Y" Diesel effects a saving of 50 to 75 per cent of the cost of steam or purchased power — with absolute dependability and less attention than is required in operating a steam plant.

The Type "Y" Diesel is a 2-cycle valveless airless injection cold starting engine — actually simpler than even a slide valve steam engine.



More than 800,000 horsepower of Fairbanks-Morse oil engines are in daily operation in industrial, central station, and marine service. This unequaled acceptance points not alone to the economy of Diesel power but to the proved dependability of the Fairbanks-Morse Type "Y" Engine.

And the pumps, too, should be Fairbanks-Morse.

Just as electric motor development took a great step ahead when Fairbanks-Morse originated ball bearing motor construction, so the use of ball bearings in the new "Fig. 850" and "Fig. 870" Fairbanks-Morse Pumps has paved the way to higher pumping efficiencies and new economies. This is simply representative of the advanced construction that is found in Fairbanks-Morse Pumps for practically every duty. Centrifugal or piston types; motor, steam or oil engine drive; gear driven, belt driven, or direct-connected.

One of our engineers will gladly give you facts and figures. Detailed information on Diesel Engines, Pumps, or combined units, will be mailed on request.

FAIRBANKS, MORSE & CO., Boston

Manufacturers Oil Engines, Pumps and Electrical Machinery

Twenty-eight branches in the United States, each with a service station.

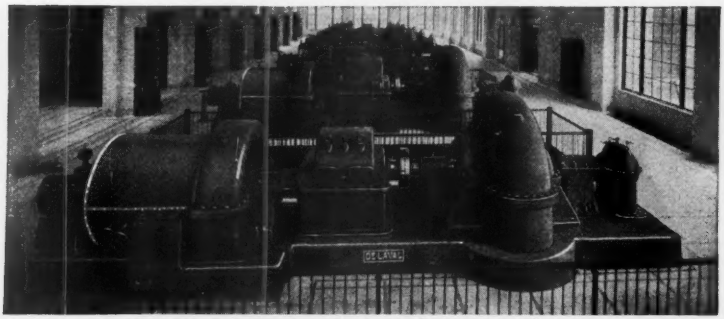
FAIRBANKS-MORSE

Diesel Engines - Pumps

DE LAVAL

CENTRIFUGAL WATER WORKS PUMPS

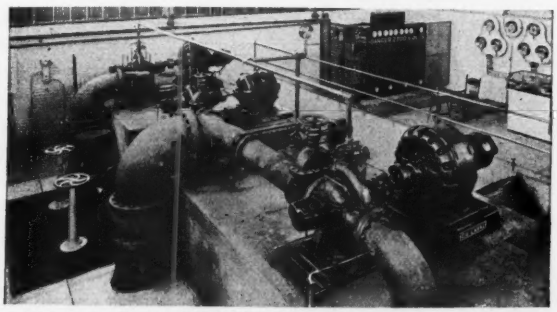
Supply 200 American Municipalities with over 5,000,000,000 gallons daily.



FAIRMOUNT PUMPING STATION, CLEVELAND, OHIO.

The largest Turbine driven pumping station in the United States. Total capacity 300 million gallons per day against heads from 85 ft. to 400 ft.

Cleveland has thirteen units installed totalling 600 million gallons per day. A fourteenth unit on order will have the unprecedented capacity of 60 million gallons against 270 ft. maximum head. Chicago has fourteen DE LAVAL units installed and on order totalling nearly 900 million gallons per day.



A TYPICAL SMALL DE LAVAL STATION, BROCKTON, MASS.

The De Laval Company announces their New England representation was transferred January 15, 1925, to

TURBINE EQUIPMENT CO. *of* NEW ENGLAND

CHAMBER OF COMMERCE BUILDING

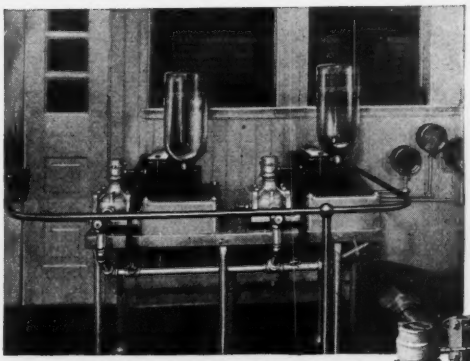
80 Federal St., Boston

This company is under the direction of F. R. C. Boyd, President, who has been connected with De Laval representation in New England for over fifteen years.

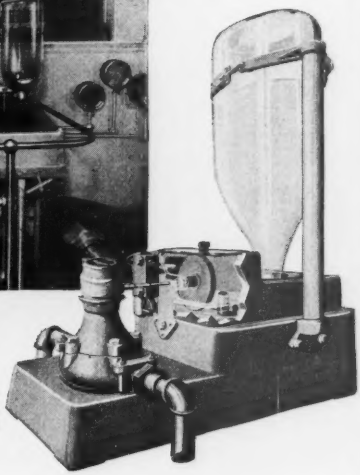
Ask for De Laval Publication.

DE LAVAL STEAM TURBINE COMPANY

Trenton, N. J.



Two W&T Chlorometers installed to sterilize the drinking water supplied to S.S. "Western States", Detroit & Cleveland Navigation Company.



Detail W&T Chlorometer showing constant level chamber, feed disc injector and drive shaft.

Now Even the Smallest Water Supplies May be STERILIZED

THE W&T Chlorometer has been developed for the automatic, proportional application of relatively small quantities of chlorine sterilizing solution.

The water to be sterilized passes through a meter.—The power obtained from the meter drives the Chlorometer.—As the water starts, the Chlorometer starts.—When the water stops, the Chlorometer stops.—The faster the water flows, the faster the solution is fed.—The slower the water flows, the slower the solution is fed.

Intended largely for small water supplies and for indoor swimming pools, the W&T Chlorometer is absolutely automatic in operation requiring no attention other than replenishing the sterilizing solution.

"The only safe water is a sterilized water"

Write for technical publication No. 55

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Founded 1853 Incorporated 1863

MERRIMAC CHEMICAL 1863 COMPANY

FILTER ALUM

Aluminum Sulphate

A basic, uniform product which has been used successfully by the leading water filtration plants in New England for many years.

Our location and shipping facilities place us in a position to offer insurpassable service and make us the logical source of supply for all filter plants in New England.

The aid and advice of our technical staff has often proved of great value to our customers. It is always at their service.

MERRIMAC CHEMICAL CO.

148 STATE ST., BOSTON, MASS.

Works:

EVERETT, MASS. WOBURN, MASS.

IN CHICAGO

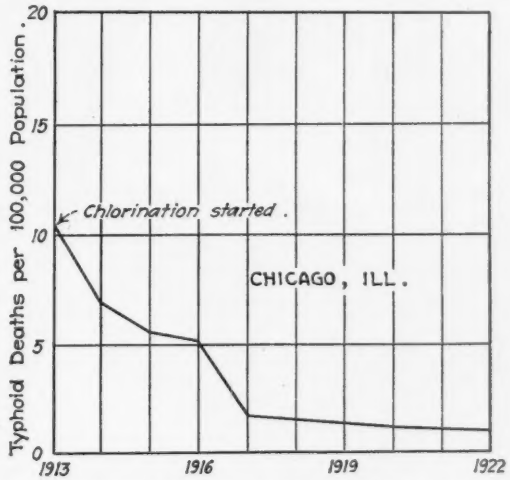

DIAGRAM SHOWS REDUCTION IN TYPHOID FEVER DEATH RATE AFTER INSTALLATION OF CHLORINE

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WHITE MOUNTAIN BRAND LIQUID CHLORINE

LINDER & MEYER

ESTABLISHED 1848

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THE BROWN COMPANY

BERLIN, N. H.

The Spiral Stripe protects you against mistakes and substitution; also look for the name and year rolled in metal.

Where Cannon Roared in '63

Sunk in the Battle of Sabine Pass

The funnel of the Union Gunboat Clifton still marks the spot, off the Texas Coast, where she went down under Confederate fire. For sixty years she has lain there, silently fighting the ever-present forces of corrosion, re-enforced by salt water and spray. But the stuff she is made of—genuine wrought iron—has withstood all these assaults. Not long ago, her walking beam, in a fine state of preservation, was recovered and mounted in Keith Park, at Beaumont.

Genuine wrought iron — made exactly as in the sixties — is the material that goes into Byers Pipe. This fact accounts for its well known quality of rust resistance.

After thirty, forty, and fifty years, whole installations of Byers Pipe, used uninterruptedly for water supply and other services, have been dug up and found almost as good as new. Authentic service records may be had for the asking.

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Established 1864

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GENUINE WROUGHT IRON

CLARK METER BOXES
METER COUPLING YOKES
METER TESTING MACHINES
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Water Works Equipment
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MATTOON, ILLINOIS
Write for Catalogue No. 24

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CAST IRON BELL AND SPIGOT
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Quotations furnished promptly for shipment from Foundry

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Heating and Plumbing Supplies
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DISTRIBUTORS OF
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With Specially Adapted
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Also Curb Cocks which eliminate Iron to Brass Corrosion both inside and out.
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"CALDWELL" WATER WORKS BRASS GOODS AND CURB BOXES
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Cast Iron Pipe

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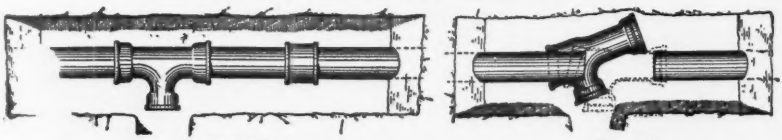
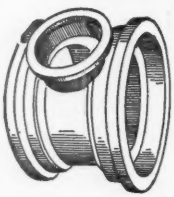


Old Way *Our Way*



Connections economically and easily made with one fitting. Saves sleeve, cuts, lead and unnecessary work and material.

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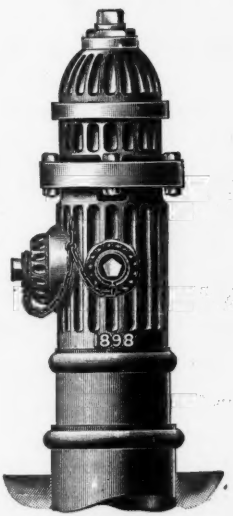
Cost of fittings reduced from 25% to 50%. Full strength. Deep bells. Convenient to handle. Sold by the piece.



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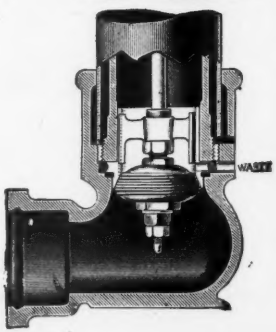
A half century of use has established their reputation as being the most economical, durable and simple hydrant.

Number in use exceeds total of all other makes combined.



Gate Valves

R. D. WOOD & CO. STANDARD
DOUBLE DISK
ANTI-FRICTION
EXTRA WEIGHT, FINISH
AND MATERIAL

A typical installation of Kennedy Valves in waterworks service. Lancaster, Pa.

Investigate Kennedy Valve records on every Municipal service

You can be sure of permanently satisfactory operation by specifying Kennedy Valves. They are time-tried and have proven their goodness in numerous important installations which have demanded the best sort of service.

The high pressure systems of New York and Boston include more than 6,000 Kennedy Gate Valves. Many Kennedys of various types and sizes are in use in other pumping stations in Chicago, St. Louis, New York, Brooklyn, Cincinnati, and other cities throughout the country.

Boston's new fire protection system, which recently proved strikingly successful on officials' tests, is controlled by Kennedy high pressure gate valves exclusively, both on mains and in the pumping stations. These cities have tested Kennedy equipment, and their experience with Kennedy reliability is evidenced by numerous repeat orders. No matter what service requirements or money outlay may be involved in your valve needs, you will be fully protected by the Kennedy experience of 48 years and our guarantee of performance.

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WATER
FILTERS
REGULATORS
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We make **Pressure Regulating Valves** for all purposes, steam or water.

Our **Feed-Water Filter** will keep oil out of your boiler.

We can interest you if you use a condenser.

Water Engines for Pumping Organs

THE ROSS VALVE MFG. CO.

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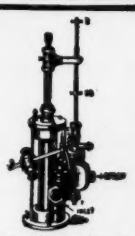

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Health and Protection First

Water delivered through dirty pipes may be a MENACE.

Incrusted water pipes mean inefficiency and loss of Fire Protection.

We Guarantee the Results of Our Method of Cleaning.

WRITE US.

National Water Main Cleaning Co.

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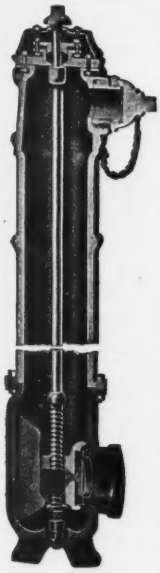

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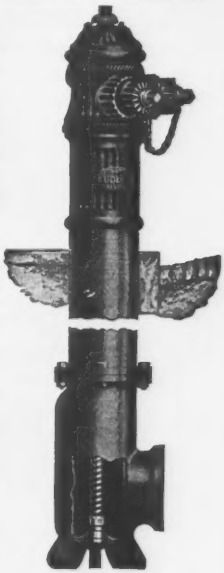
VALVES and FIRE HYDRANTS

This hydrant is anti-freezing, because when the drainage is good no water is left in it to freeze.

The drip is directly in the bottom of the hydrant and drains perfectly. It is protected by its valve, which never leaves its socket and cannot be clogged.



DOUBLE AND SINGLE GATE **VALVES,** ALSO CHECK **VALVES,** FOOT **VALVES.**

FIRE **HYDRANTS.**

YARD, WASH, AND FLUSH **HYDRANTS.**

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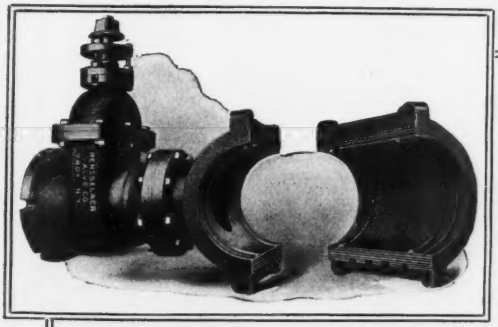

Rensselaer Tapping Sleeves

were brought out to meet a growing demand for a "BETTER" Tapping Sleeve. They were designed to suit conditions met in actual practice.

They can be used with all standard makes of Tapping Machines.

POINTS OF
SUPERIORITY

Have two lead rings.

Require less lead for calking.

Iron washers not required.

Bolting flanges are made full length of sleeve, giving great strength.

Have greater thickness of hubs on ends.

Easier to center on pipe before pouring lead.

Cost less to install.

Book No. 11 gives full information.

Ask for prices.

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New England Sales Manager, Lock Box 2, Northboro, Mass.
RENSSELAER VALVE COMPANY, TROY, N.Y.

THE CHAPMAN VALVE MANUFACTURING COMPANY

Manufacturers of

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Gate Fire Hydrants

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EDDY VALVE CO.

WATERFORD, NEW YORK U.S.A.

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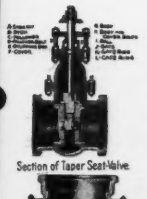
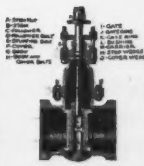
EDDY FIRE HYDRANT



Section of Taper Seat Valve.

Hydrant with Independent Nozzle Cut-off.



Section of Parallel Seat Valve.

Section of Vertical Check Valve.

Section of Vertical Foot Valve.

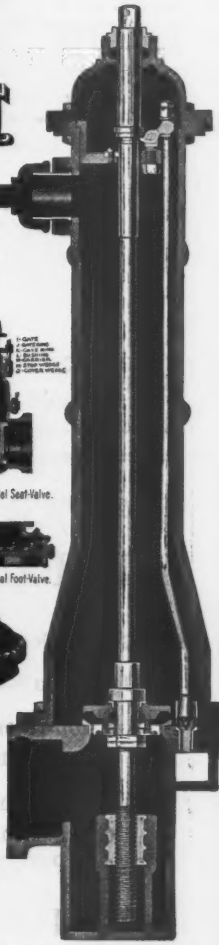
Horizontal Check Valve.

Vertical Foot Valve.

Hydrant with Water Crane Attachment.

Indicator Post.

Water Crane with Automatic Drip Valve.



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All Goods made by the EDDY VALVE COMPANY are manufactured exclusively at WATERFORD, N.Y., U.S.A.

VALVE CLOSED—DRIP OPEN.

EMAUS PIPE FOUNDRY,
DONALDSON IRON CO.,

MANUFACTURERS
...OF...

CAST IRON PIPE

...AND ..

Special Castings for Water and Gas.
Also Flange Pipe, Street Castings,
Manhole Heads and Covers, etc.

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EMAUS,
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WATER WORKS SUPERINTENDENTS!

Is your per capita consumption too high?

Do you account for less than 85% of your pumpage?

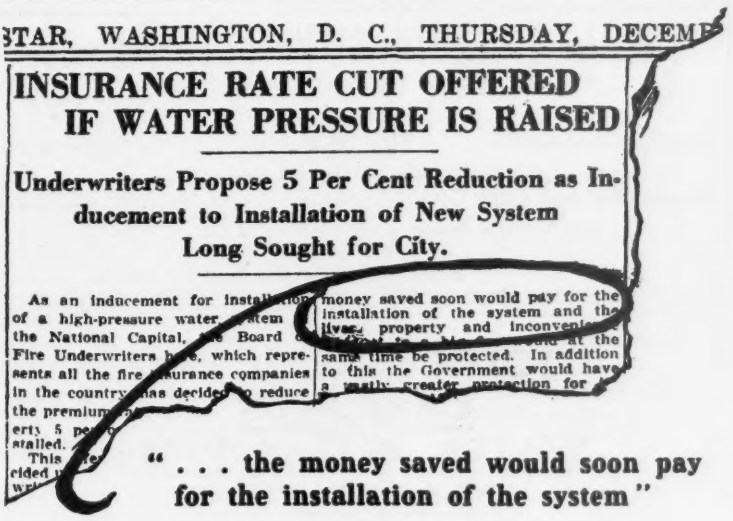
Are you receiving full revenue from your manufacturing consumers?

If any of these problems confront you, write us at once, without obligation, and let us tell you about our PITOMETER SURVEYS.

THE PITOMETER COMPANY

Engineers

50 CHURCH STREET, NEW YORK CITY, N. Y.



STAR, WASHINGTON, D. C., THURSDAY, DECEMB

INSURANCE RATE CUT OFFERED IF WATER PRESSURE IS RAISED

Underwriters Propose 5 Per Cent Reduction as Inducement to Installation of New System Long Sought for City.

As an inducement for instal... of a high-pressure water ...stem ... the National Capital, ... Board ... Fire Underwriters ..., which represents all the fire ...surance companies in the country, has decided to reduce the premium ... erty 5 pe... stalled. This ... cided ... wi...

money saved soon would pay for the installation of the system and the ... property and inconveni... ...sold at the same time be protected. In addition to this the Government would have a vastly greater protection for ...

" . . . the money saved would soon pay for the installation of the system "

LARGE cities throughout the country have learned that an independent high pressure system is a good investment.

Standard Bell and Spigot high pressure Cast Iron Pipe has distinct advantages over other materials. It is flexible, tight and free from corrosion. It is also safe from any danger of collapse where the empty main system is used.

Write for copy of "United States Cast Iron Pipe Handbook," it contains valuable data for engineers.

United States Cast Iron Pipe and Foundry Company

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Tapping Machines, Fire Hydrants, Water Gates,

Economic Lead Furnaces,

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Also General Supplies for Water and Gas Works.

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WATER & GAS PIPES

FLANGE PIPE

Special Castings, Fire Hydrants, Valves

General Foundry and Machine Work

WOOLWORTH BUILDING 233 BROADWAY

NEW YORK CITY

HIGHEST AWARD, GOLD MEDAL,
ST. LOUIS EXPOSITION, 1904

Over 100 Water Departments

use

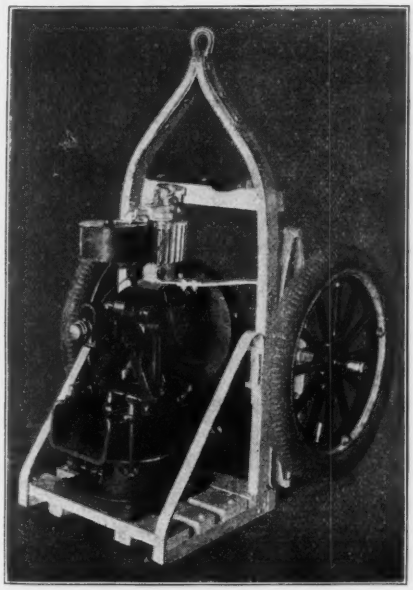
LEAD-LINED IRON and TIN-LINED PIPES

for their service connections

MANUFACTURED BY

Lead Lined Iron Pipe Company

Wakefield Mass.



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Bell and Spigot Flanged Pipe
Special Castings
Flexible Joint Pipe Cylinders

Water Gas Sewers Culverts

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LARGE STOCK ENABLES US TO MAKE QUICK SHIPMENTS

Twelve Reasons Why

YOU SHOULD USE

Trade "LEADITE" Mark

Registered U. S. Patent Office

FOR

Jointing Water Mains

1. **DURABILITY.** Leadite joints increase in strength with age.
2. **NO CAULKING.** Leadite joints require no caulking, because the Leadite adheres to the pipe, making a water-tight bond.
3. **COMPARATIVE QUANTITIES.** One ton of Leadite is equivalent to four tons of lead.
4. **LABOR SAVING.** Saves caulking charges and digging of large bell-holes, and reduces the cost of trench pumping to the minimum.
5. **COST.** Its use saves 50 to 65 per cent. over lead, owing to the saving effected in material and labor.
6. **TOOLS.** As no caulking is required, fewer tools are needed.
7. **TRANSPORTATION.** Considerable freight charges are saved because Leadite is lighter than lead.
8. **HAULING.** Saves hauling expense on the work because you move only one fourth the weight of jointing material.
9. **FUEL.** Saves fuel because you melt only one ton of material instead of four, and not as much heat is required either.
10. **DELIVERY.** We can make prompt shipments.
11. **DAMAGE SUITS.** Claims for damages caused by joints blowing out are prevented because Leadite joints will not blow out under any pressure.
12. **USERS.** Progressive water works all over the country use Leadite.

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The LEADITE COMPANY, Inc.

Land Title Building **Philadelphia**

P. E. KELLY, New England Representative

8 TRENT STREET **ARLINGTON, MASS.**

Chadwick-Boston Lead Co.

162 Congress St., Boston

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The Celebrated "ULCO"

LEAD WOOL

(Every Atom Pure Lead)

For calking pipe joints under the most difficult conditions.

For overhead joints, or in wet places where the use of molten lead is not only impracticable but dangerous — **LEAD WOOL** may be used to advantage.

It makes an absolutely tight joint which will withstand the highest pressure, yet be sufficiently elastic to allow considerable sagging or settling of the pipe without danger of a leak.

As compared with the poured joint, in this respect, the superiority of **LEAD WOOL** is apparent.

Manufacturers of

Lead Pipe, Tin Lined Lead Pipe, Pure Block-Tin Pipe, Solder, White Lead and Red Lead.

HIGHEST QUALITY SOFT BRANDS

PIG LEAD

TEN CENTS PER POUND PRICE TEN CENTS PER POUND PRICE TEN CENTS PER POUND TEN CENTS

Join Your Water Mains

WITH

LEAD-HYDRO-TITE

TRADEMARK

AND CUT YOUR EXPENSES

50% FIRST COST

50% SMALLER BELL HOLES

75% HANDLING

100% CALKING

OUR PROPOSAL

That the prospective users purchase a trial lot of 1 to 5 bags, and that this be used under the direction and according to the instructions of our representative.

If, after a trial, the purchaser is not satisfied with the material, any surplus not used to be returned to the Hydraulic Development Company, and no charge to be made for any of the Hydro-Tite furnished.

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Hydraulic Development Company

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TEN CENTS PER POUND PRICE TEN CENTS PER POUND PRICE TEN CENTS PER POUND TEN CENTS

"The Goods That Please"

Corporation and Curb Cocks

We have them to meet every requirement

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"Hays-Erie"

Extension Service Boxes of proven advantages

Let us send at our risk, on 30 days' trial, a

Payne's Patent Tapping Machine

which is recognized to be the most easily operated owing to the few working parts.

Hays Mfg. Co., ERIE PENNSYLVANIA

Established 1869

Freedom from leakage and ease of installation

You can do everything with Universal Pipe that you can do with ordinary cast iron pipe . . . . and more. All jointing materials eliminated.

no lead, no pouring, no bell holes

Standard six-foot lengths convenient to handle, easy to lay. Experienced labor unnecessary.

Used the country over for dependable water supply and fire protection lines. Our nearest office is at your service.

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THE CENTRAL FOUNDRY COMPANY

Subsidiary of

The Universal Pipe and Radiator Company

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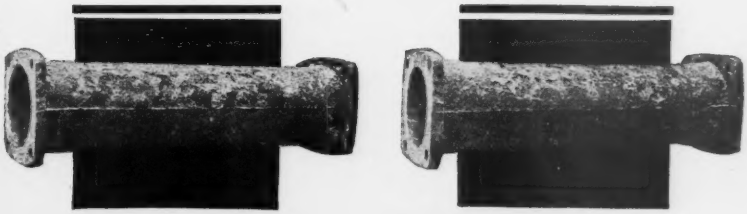
Sales Offices: New York Chicago Birmingham San Francisco Los Angeles

French Cast Iron Pipe praised by American Pipe Makers



Still in Service After 250 Years

These two sections of pipe, taken from the centuries-old cast iron pipe installation at Versailles, have been brought to this country for exhibit purposes, and are on display at the offices of B. Nicoll & Company, Inc., New York.

As an outstanding example of cast iron pipe superiority, American pipe makers point to the cast iron pipe installed at Versailles in the reign of Louis XIV. The French knew how to make pipe then, and they know how today.

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* "P-À-M" Pipe Immediate shipment. All Sizes. Large Stocks ready for delivery in American ports within thirty days.

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A. W. W. A. Specifications

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General Agents in the United States

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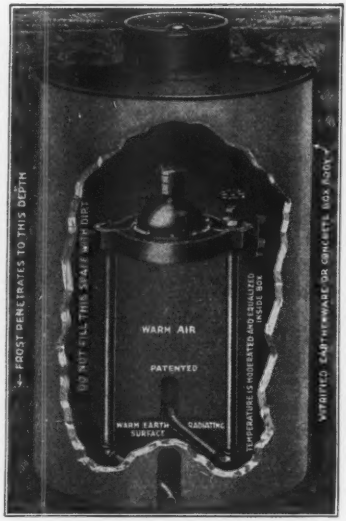
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PATENTED
WARM EARTH SURFACE
RADIATING
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Manufacturers Water Works Equipment

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Lit-tle Drop-o'-Wa-ter in Tu-ber-cu-lat-ed Pipe

I am lit-tle Drop-o'-Wa-ter.

I sail out on the Big Sea. I am drawn up in-to the Cloud. I drop down, as Rain, on the Earth.

I love to sail and to fly; but I have my most in-ter-est-ing ex-pe-ri-en-ces be-tween the times I fall as rain and when I sail out on the Big Sea.

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Lit-tle Drop-o'-Wa-ter in "Lock Joint" Pipe

But ver-y fre-quent-ly we start through Lock Joint Re-in-forced Pres-sure Pipe. And, then, how we laugh! We know that there will be no bumps, for the walls and joints of such pipe are al-ways per-fect-ly smooth and nev-er tu-ber-cu-late.

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Pressure: Sewer: Subaqueous

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about service pipe problems

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New England Water Works Association.

ORGANIZED JUNE 12, 1882.

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